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RUDOLPH E. VOIGT,	207 California Street, S. F., Cal.
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[Arranged Alphabetically by Cities.]

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University Observatory, Leipzig, Germany.

Royal Observatory, Lisbon, Portugal.
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British Astronomical Association, London, England.
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Royal Astronomical Society, London, England.
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University Observatory, New Haven, Connecticut.
Observatory, Nice, France.
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University Observatory, Oxford, England.
Royal Observatory, Palermo, Italy.
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Astronomical Society of France, Paris, France.
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Observatory of the Roman College, Rome, Italy.
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Observatory, Santiago, Chile.
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Naval Observatory, Washington, District of Columbia.
Smithsonian Institution, Washington, District of Columbia.
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Field Observatory, Williamstown, Mass.
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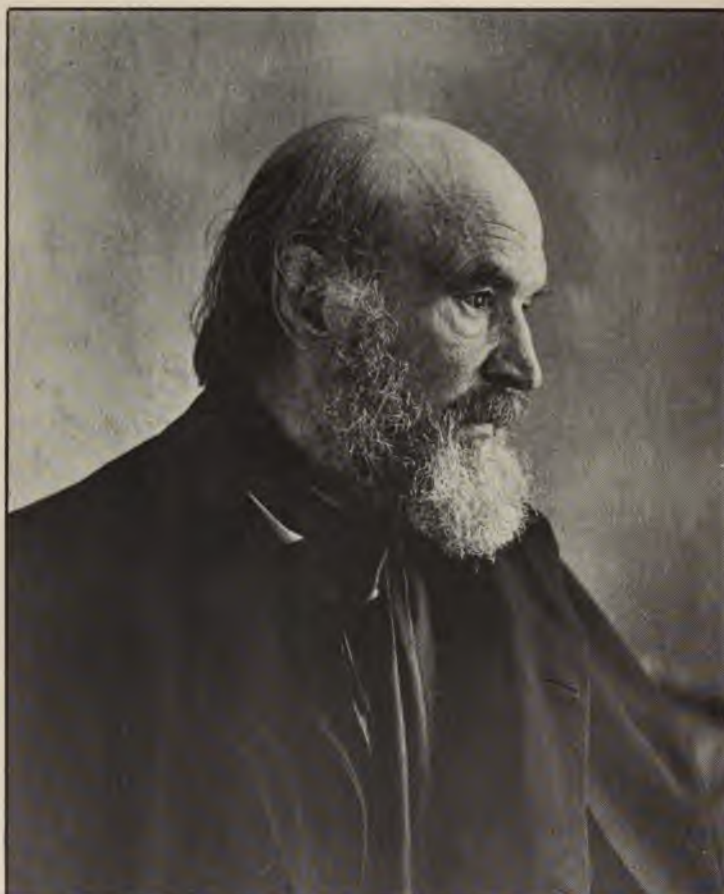

JOHN COUCH ADAMS.
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WHEN SHALL WE HAVE ANOTHER GLACIAL EPOCH?

BY GARRETT P. SERVISS.

The enunciation by Sir ROBERT BALL of the fact, which seems to have been first clearly brought to light by him, that of the total amount of heat falling from the sun in a year, upon either the Northern or the Southern hemisphere, 63 per cent. is received in summer and 37 per cent. in winter, has awakened renewed interest in the problem of the glacial epochs. Dr. BALL's theorem not only strengthens the astronomical explanation of the cause of such epochs, but also adds to its clearness. This explanation may be summed up in a few words.

It must be remarked, to begin with, that the summer and winter here spoken of divide the whole year between them, the equinoctial points marking the lines of division, spring and autumn being merged into the greater seasons. Everybody knows that summer in the Northern hemisphere, counting summer as extending in the broader sense just mentioned from the vernal to the autumnal equinox, is about seven days longer than winter. In the Southern hemisphere just the opposite condition prevails. This difference arises from the eccentricity of the earth's orbit. If the orbit were a circle instead of an ellipse, winter and summer would be of equal length.

But the elliptical orbit of the earth is not absolutely fixed, either in form or in its position in space. Owing to the varying attractions of the other planets, and more particularly of *Venus* and *Jupiter*, the earth's orbit is alternately rounded up almost into a circle, and then drawn out into a more eccentric ellipse. These changes require vast intervals of time, so that we must go far back into the geological ages in order to obtain evidence of

their effects upon the earth. But it is clear, theoretically, that great seasonal vicissitudes must result from such variations in the form of the earth's orbit. When it approaches nearly to a circle, which is its condition now, the difference in the length of summer and winter is small; when it is in its state of greatest eccentricity, the difference is large, amounting under the most favorable circumstances to as much as thirty-three days, or some authorities say even more, instead of seven days, its present amount.

Now the theory in question asserts that the glacial epochs in the history of the earth have occurred during those periods when, the eccentricity of the orbit being large, the difference in the length of summer and winter was at or near a maximum. Such a maximum will, of course, occur whenever the line of equinoxes is perpendicular to the major axis of the orbit. Under such circumstances one hemisphere would have 199 days of winter and 166 days of snmmer, while the other hemisphere had 166 winter and 199 summer days. But there would be no difference in the distribution of the heat coming from the sun. Just 63 per cent. of it would continue to be received in summer and 37 per cent. in winter in each hemisphere. The hemisphere which had 199 days of winter, would have to spread the 37 per cent. of heat belonging to that season over all those 199 days, while the 63 per cent. of summer heat would be concentrated upon the shorter period of 166 days. Accordingly there would be a very long and cold winter, followed by a short and hot summer. The heat of the latter would not suffice to melt away the snow and ice accumulated during the former, and this accumulation would go on until whole continents were buried under a blanket of ice thousands of feet thick. In the other hemisphere there would be, on the contrary, a short, mild winter and a long summer. So glaciation in one hemisphere would be accompanied by genial climatic conditions in the other.

Such is, in brief, the outline of the astronomical theory of the cause of glacial epochs. I have purposely used the plural in describing such epochs, although we commonly hear only one ice age spoken of, because one of the most interesting points about this theory is that while accounting for that age of ice whose handiwork is so familiar to geologists in the Northern hemisphere, it also demonstrates that there must have been many glacial epochs of varying intensity in the past, and that there will be many more in the future.

This wonderful thing, the burying of half of North America and the greater part of Europe under ice, and the absolute destruction of all their manifold forms of life, can then happen again, nay, must happen again. Naturally, the question arises, when? A precise answer cannot be given, owing to the intricate nature of the causes at work, but it seems possible to give an approximate answer. Dr. JAMES CROLL, in his work on "Climate and Time," has computed the periods of greatest and least eccentricity of the earth's orbit for a million years to come, and for a still greater period of time in the past. About 852,000 years ago the eccentricity attained its greatest possible amount. From 240,000 down to 80,000 years ago the orbit continued to be very eccentric, and Dr. CROLL's conclusion was that the latest ice age in the Northern hemisphere ended with the close of the period of high eccentricity, 80,000 years ago.

In the future, according to Dr. CROLL's tables, the earth's orbit will become highly eccentric about 150,000 years from the present epoch. Until that time, it appears, we shall be reasonably secure from any invasion of the ice. But the eccentricity then to be attained will be by no means the greatest possible. It will amount, according to Dr. CROLL, to 0.0353 as against 0.0168 at present, so that even if a glacial epoch then occurs it will probably not be so severe as some of those that have occurred in past time, or some that may be expected in the future. But there are three future periods of very great eccentricity indicated by Dr. CROLL, which will attain their maxima in 800,000, 900,000 and 1,000,000 years respectively from the present time, and when glaciation in its severest form may occur in one hemisphere or the other, or more probably in both alternately. Dr. CROLL's estimates of the eccentricity of the earth's orbit at the three dates just mentioned are 0.0639, 0.0659 and 0.0528.

It is interesting to note that during the periods of minimum eccentricity to which Dr. CROLL calls attention as separating these three periods of high eccentricity, the orbit will be even less eccentric than it is at the present. The minima will occur in 850,000 years, with the eccentricity at 0.0144, and in 950,000 years, with the eccentricity at 0.0086. But, both the descent from the high eccentricity of 800,000 years hence to the minimum in 850,000, and the subsequent ascent to the maximum in 900,000, are very sharp and steep, and the same is true of the next following minimum and maximum in 950,000 and 1,000,000. In view of these

facts one is tempted to speculate as to the chances of recovery that the animal and vegetable forms of the regions afflicted by glaciation during these coming periods of high eccentricity would have in the comparatively few thousand years of respite from the ice that would intervene between the maxima.

It will be observed that while ice ages are unquestionably recurrent phenomena, yet they are not separated by anything like regular intervals of time, simply because the conditions favoring their production do not recur at regular intervals, but are the result of exceedingly complex influences. Moreover, ice ages come in pairs or sets, alternating between the Northern and Southern hemispheres. This fact arises from the precession of the equinoxes, by which, once in every 10,500 years, an interchange of condition is effected between the hemispheres. At present, for instance, we in the Northern hemisphere have our winter when the earth is nearest to the sun, and it is seven days shorter than the summer. In the Southern hemisphere, on the other hand, winter occurs when the earth is furthest from the sun and is seven days longer than the summer. If the eccentricity of the earth's orbit were as great now as it will be 150,000 years from now, and more particularly as it will be 800,000 years hence, the Southern hemisphere at present would be suffering from a glacial epoch, while we should enjoy short, mild winters and equable summers, longer than those we have now, but not quite so hot. In about 10,500 years, however, a complete interchange will have taken place, and then our hemisphere will have its winters when the earth is furthest from the sun, and its summers when it is nearest. It will hardly be so comfortable in the United and Europe then as it is in our day, although no glacial invasion is to be expected.

It is because the periods during which the earth's orbit remains greatly eccentric when once drawn out by planetary attraction, are far longer than 10,500 years, that two or more successive ice ages may occur in each hemisphere during the prevalence of a single period of high eccentricity. If the condition of great eccentricity were a phenomena of comparatively brief duration, both hemispheres might escape glaciation during such a period, because it might happen that, while the orbit was drawn out into its extreme state of eccentricity, the equinoxes would nearly coincide with the apsides, and so winter and summer would be of equal duration.

As long as no outside influence interferes with the regular procession of the planets, and the astronomer cannot foresee although he may admit the possibility of such interference, we may count upon our globe remaining a genial abode, neither too hot nor too cold, though subjected to some vicissitudes of climate; and long before the next period of high eccentricity has blasted our fair continent with the chilling breath of the glaciers, the race of man may have had its day.

POGSON'S COMET AND THE BIELAN METEORS.

By W. H. S. Monck, Dublin.

The story of Pogson's discovering a comet in the year 1872 is pretty well known. Klinkerfues, after the great shower of Nov. 27th, 1872, telegraphed to Pogson, at Madras, that Biela's comet had touched the earth and asked him to look out for it near *θ Centauri.* Pogson did so as soon as the weather permitted and saw a comet in the direction indicated on the 2d and 3d of December. Subsequent computations, however, led astronomers to conclude that Biela's comet could not have touched the earth on the day in question, nor if it had done so, would it have been seen in the place where a comet was observed by Pogson.

The reason, however, why Klinkerfues placed the comet near *θ Centauri* does not seem to be so well known. The radiant point for meteors attached to Biela's comet is situated at about 25°, +44°. But Klinkerfues deduced from the paths of 81 meteors observed on the 27th of November, 1872, a radiant at 26°, +37°. He seems to have concluded from this radiant that Biela's comet had changed its course and that its new path would bring it near *θ Centauri;* and the discovery of a comet near that star by Pogson affords some confirmation of the correctness of Klinkerfues's radiant. It is true, indeed, that the majority of observers in 1872 placed the radiant nearer to 25°, +44° than Klinkerfues, but the radiant is admittedly a very diffused one and it cannot be said that Klinkerfues stands alone in his determination of it. Swift, at Rochester, N. Y., placed it at 26°, +39° during the latter part of the shower and Denza placed one extremity of the radiant (which he described as an area) at 25°, +38°. From what we know of the break-up of Biela's

comet there is no improbability in its having thrown off at some earlier period the comet observed by POGSON; or if they never formed parts of the same comet, the comets of POGSON and BIELA may belong to the same family and may co-operate in producing the same diffused meteor-shower.

Another great display of BIELAN meteors took place in 1885. It is natural to inquire whether any meteors from KLINKERFUES's radiant were observed on that occasion. I find on the 4th of December, 1885, Mr. DENNING deduced a radiant at 31°, +37° from a number of slow-trained meteors of the BIELAN type, and he places November 30 and December 7 under the head of "other nights of observation." Dr. KLEIBER has computed parabolic orbits for all the radiants in Mr. DENNING's catalogue and I find that his elements for this shower agree closely with those of the BIELAN shower a few days earlier. I give these elements compared with those of the shower observed at 24°, +44° on the 27th of November in the same year. These showers are numbered 819 and 851 in Mr. DENNING's catalogue.

	No. 819.	No. 851.
π..........	109°.8	114°.5
Ω..........	249°.5	253°.0
i..........	15°.7	11°.5
q..........	0 .847	0 .861

The motion in both cases is direct.

If POGSON's comet was pursuing an orbit similar to that of BIELA's it would nearly complete three revolutions in 20 years. If it was near the node in November, 1872, it would be a considerable distance from it in November, 1885, which would account for the feebleness of the shower noted by Mr. DENNING on the 4th of December in that year. But it ought to be again near the node about the 1st of December, 1892, when we might hope to detect the comet itself as well as a renewal of the meteor-shower which led KLINKERFUES to its discovery. It should, however, be mentioned that one of Mr. DENNING's stationary or long-enduring radiants is situated very near 31°, +37°, which renders the connection of this shower with any comet somewhat problematical.

As POGSON obtained but two observations of the comet, no orbit could of course be determined from his data. But if the comet is one of short period like that of BIELA and the meteor-showers which I have mentioned were connected with it, some of

the skilled mathematicians who belong to this society may find the data sufficient for computation. A rough determination for the guidance of comet-seekers would answer all practical purposes.

HISTORICAL NOTE RELATING TO THE SEARCH FOR THE PLANET *NEPTUNE* IN ENGLAND IN 1845–6.

By Edward S. Holden.

In 1876 I was in England for several months and one of my greatest privileges was the acquaintance and friendship of Mr. Lassell, the celebrated astronomer, whom I frequently visited. During one of my visits to Ray Lodge I learned the following circumstances from Mrs. Lassell and they were subsequently confirmed and explained to me by Mr. Lassell himself.

With the innate delicacy of his character he had taken every precaution that they should not become known during the lifetime of Professor Adams, and I think he seldom or never alluded to them. At this time, when the great mathematician has gone from us, it seems to be right that they should be mentioned and, with the permission of the Misses Lassell, I reproduce in what follows the brief notes I made at the time of Mr. Lassell's confidences, as a contribution to the history of the great discovery of Adams and of Le Verrier.

It is known that in October, 1845, Professor Adams, then an undergraduate of Cambridge, submitted to Sir George Airy, Astronomer Royal, the results of his computations on the perturbations of *Uranus* and the elements of a new planet—*Neptune*—which would account for the observed disturbances in the orbit of the former.* The distinguished observer, the Rev. W. R. Dawes, visited the Royal Observatory about this time, and the letters and computations of Adams were shown to him by Airy. It is known that the Astronomer Royal had, very naturally, grave doubts as to the sufficiency of these researches; but it appears that Dawes was much impressed by the letters of Adams, and that he at once wrote to Lassell to beg him to search for *Neptune*, in the region designated by Adams, with his powerful two-foot reflecting telescope (which was then mounted at Starfield, near Liverpool).

There is no doubt whatever if such a search had been made

* See Gould on the History of the Discovery of *Neptune*. Washington, 1850.

by such an observer and with such a telescope, that the planet would have been quickly found and recognized by its disc. We have but to remember that to the same telescope and observer we owe the discovery not only of the satellite of *Neptune* but also that of the two inner and faint satellites of *Uranus*.

It chanced that the letter of Mr. DAWES reached Liverpool when Mr. LASSELL was confined to his sofa by a sprained ankle, and that it was laid on his writing table near by for subsequent attention. Mr. LASSELL, also, was impressed with the importance of a search for the predicted planet and had fully resolved to make such a search.

After his recovery he sought for the letter of Mr. DAWES which gave the predicted place of the planet. The letter could not be found as it, together with some other papers, had been removed and destroyed by a too zealous maid-servant.

I think, though I am not sure, that renewed inquiry was made by LASSELL of DAWES as to the data in question. However this may have been, they were never recovered, and the mistaken zeal of the maid-servant had its full effect.

The new planet was never sought for by the most powerful telescope and the most skilful observer in England. The search of CHALLIS, at Cambridge, was fruitless, as is well known. The planet was finally found by GALLE and D'ARREST, at Berlin, on September 23, 1846, after the Berlin Observatory had received the letter of LE VERRIER pointing out its situation.

This was many months after the letter of DAWES to LASSELL.

This incident of the history of the search for *Neptune* is well worthy of record, as it shows by what a narrow chance Professor ADAMS escaped the distinction of being the *sole* discoverer of *Neptune*.

It is also worthy of remark how this and other accidents have helped to forward the Science of Astronomy. England had no higher rewards and opportunities to offer than those which she has given to ADAMS. But if LE VERRIER had been deprived of his share in the discovery it is very much to be doubted whether we should now possess that long series of elegant and laborious researches which he was able to carry out by the facilities afforded him in his situation as head of the National Observatory of France.

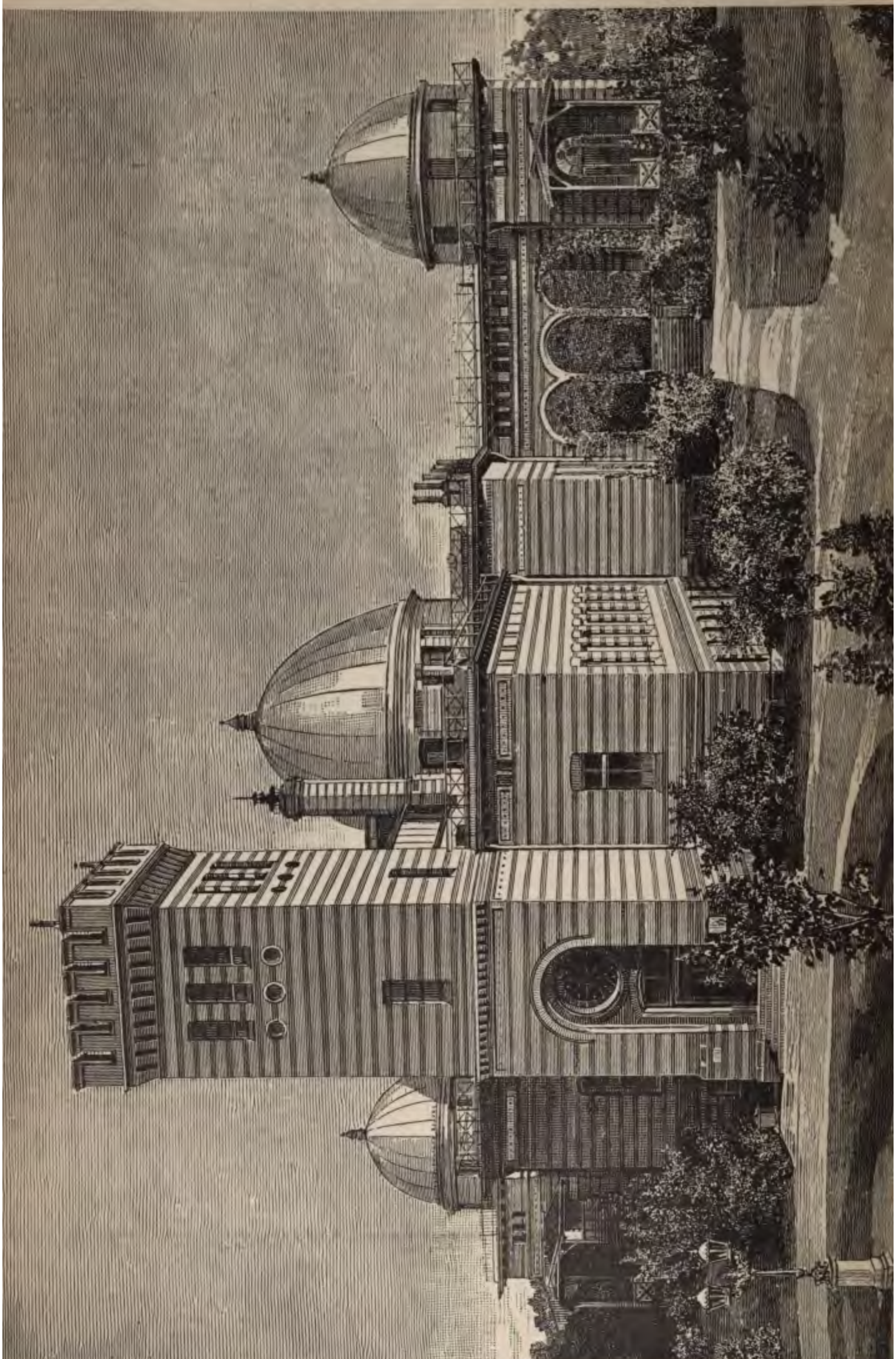
The whole relation of Professor ADAMS to this great discovery is again called up by this incident and the elevation of

his character and the dignity of his conduct are again brought to mind.

The delicate consideration of Mr. LASSELL, who for a long lifetime kept this secret in order that no possible shade of regret should be inspired during the lifetime of Professor ADAMS, is no less honorable. It is a pleasure to be able to link in this way the name of England's great mathematical astronomer with the name of her great observer—worthy successors of NEWTON and of HERSCHEL as they were.

MOUNT HAMILTON, January 30, 1892.

NOTE: By the great kindness of a friend in England I am able to reproduce here the last picture taken of Professor ADAMS, which was made in Cambridge in September, 1891.



NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

THE NATIONAL OBSERVATORY OF THE ARGENTINE REPUBLIC.

In 1870 Dr. B. A. GOULD arrived at Cordoba, in the Argentine Republic, bringing with him some of the appliances necessary for the establishment of the National Observatory.

Owing to delays of various kinds, many of which were due to the Franco-German war of 1870, the meridian circle was not in position till 1872. The two years, 1870–72, were spent—and well spent—in the formation of the *Uranometria Argentina*, which shows the brightness and position of every star visible to the naked eye in the southern heavens; that is in about $\frac{41}{70}$ of the whole sky.

This work was done by Messrs. THOME, ROCK, DAVIS and HATHAWAY under the direction of Dr. GOULD and according to plans which he had matured since 1858. The scale of magnitudes adopted was the same as that employed by ARGELANDER in making his *Uranometria Nova* (1843) which contains the positions and brightness of all the lucid stars (3256 in number) visible at Bonn. ARGELANDER'S faintest star was 6th magnitude. It was found that stars of less than the 7th magnitude could be seen in the clear sky of Cordoba, and in fact the *Uranometria Argentina* contains 8198 stars of the 7th magnitude and brighter, while 2451 stars fainter were observed but have been excluded. Of these 10,649 stars more than 46,000 observations were made. The work was done in the most thorough manner and will remain a classic always. It was published in 1879.

As soon as the meridian circle was installed (1872) it was at once set to the work planned by Dr. GOULD. This was first to form a catalogue of standard stars (32,448 in number) and second to form a catalogue of zone-stars in the regions south of ARGE-

LANDER'S zones and north of the (unpublished) zones of GILLISS, that is in the region $-31°$ to $-65°$ (73,000 stars in all).

This work was completed, so far as observation was concerned, in 1881.

The following observations had then been made:

For the standard catalogue	121,000
For zero stars	14,000
For stars in the zones	105,000
	240;000

About half of these were made by Dr. GOULD himself, assisted by various observers. Dr. THOME took a leading part in this work, also, from the beginning. The catalogue of zone stars was published in the year 1884 and the catalogue of standard stars in 1886.

These three great undertakings were thus brought to a successful termination, and the Cordoba Observatory has given us data for the southern sky which is comparable in amount and in several respects superior in accuracy to the corresponding data for the northern. Besides these principal works, other series of scarcely less value were carried on relating to the observations of comets and asteroids, to the determination of geographical positions, to the observation of variable stars, to the photography of star-clusters, to South American meteorology, etc., etc.

The *results* of the work of the Cordoba Observatory were thus quickly put in the hands of astronomers. The data upon which these results depended were to be printed in the annual volumes. Dr. GOULD resigned his position in 1885 and Dr. THOME was appointed in his place, and the work of publishing these annual volumes fell upon the latter, as well as the carrying out of a plan of Dr. GOULD'S for making a complete *Durchmusterung* of the southern sky, which should contain the position and brightness of every star brighter than the 10th magnitude. These annual volumes have been prepared and the last of them (Vol. XIII) is now in the press. The preface to this volume has just been received and it is printed below, as it marks the termination of what may be called the first period of the activity of this great observatory.

It was founded in 1870 through the active interest of Dr. SARMIENTO, President of the Republic. It has been willingly and generously supported by successive congresses from that time to this. The programme of its work was carefully laid down by

Dr. GOULD and has been loyally followed by Dr. THOME. These gentlemen have been faithfully assisted by many observers, usually North Americans.

Science has no country and the priceless results which have been attained belong to the whole world. Yet it is permissible to rejoice that it is to American astronomers, GILLISS, GOULD, THOME and their assistants, that many of the chief advances in our recent knowledge of the stars of the southern sky are due; and this much can be said while giving the fullest credit to the labors of other astronomers in the southern hemisphere.

The preface written by Dr. THOME follows, and I hope that the work of which it treats will be even better appreciated because of this slight introductory note which I have written.

EDWARD S. HOLDEN.

Preface to Volume XIII of the Cordoba Observatory Publications.

BY J. M. THOME, Director.

"With the present volume, the publication of the separate determinations made in the years 1872-1880 is completed, and they are now embodied in permanent form, secure against all temporal vicissitudes. This labor has been carried on uninterruptedly for the past six years, during which period seven volumes have appeared. The time and labor required in the revision have been very great, no pains having been spared to secure accuracy in every case of doubt, and I now have reason to believe that, after making the corrections indicated in the lists of errata accompanying each publication, the entire series of fourteen volumes will be found nearly perfect.

It is for me a source of sincere congratulation that I have been able to perform this service. These results were obtained only after many years of rude labor, unfailing energy and vigilance, and it was due that they should be published with loving care. Having been associated with the Observatory from the beginning, occupying the nominal Directorship during the progress of these observations for periods amounting to more than two years, and having contributed a larger part to the formation of these Catalogues than any other assistant, there was no one, probably, who could have so intimate a knowledge of the requirements for their proper publication after Dr. GOULD, to whom they owe their origin.

Meanwhile, the regular programme of observations has been continued uninterruptedly with good results, in spite of many vexatious and disheartening occurrences and malicious combinations. The chief object has been the extension of the Southern Durchmusterung from the limit to which it had been carried by the lamented Dr. SCHÖNFELD. This we have succeeded in doing as far as to the parallel of 42°, and we have made in that region (22° to 42°) more than a million observations, representing over 300,000 positions and magnitudes of stars and nebulae to the 10.0 magnitude inclusive. These observations were begun at the end of the year 1885, and the first installment of Results has been given to the printer. We have, besides, obtained something more than 30,000 determinations of stellar positions upon the meridian, a large series of observations of comets and of the minor planets, numerous latitude and longitude determinations, and some fine long-exposure photographs with the new telescope by WARNER & SWASEY.

It is a grateful pleasure to acknowledge here to the illustrious men of science of every nation the generous aid and the unvarying interest shown by the National Government in the affairs of the observatory during the momentous occurrences of the past few years and the actual crisis of the present. In spite of the clouds that hang over this noble and generous people now, the Nation is destined to emerge triumphant, in a few years, and to again assume the leadership, morally and physically, among the Governments of South America.

My especial thanks are also due to the distinguished astronomers Dr. AUWERS, of Berlin, Dr. GILL, of the Royal Observatory of the Cape of Good Hope, and to my venerated chief, Dr. GOULD, for their generous encouragement and advice.

The present volume contains the observations made during the year 1880 for the General Catalogue. The number of separate determinations was 33,837, giving the mean places of 10,923 stars. For all of these, four microscopes and eleven transit threads were employed, except for the time stars, in which case seventeen transits were recorded.

The dimensions of the volume almost entitle it to the rank of a General Catalogue, and the results for the month of December, alone, when 5938 determinations of positions were made, would

form a fair Annual Catalogue.* A few words of explanation may be necessary.

About the middle of the month of July, 1880, when one-third of the total number of observations for the year had been made, Dr. GOULD was called away for the remainder of the year upon a special mission, and the temporary Directorship was assigned to me. As this was to be the last year of special observing for the General Catalogue, the desire to signalize the event by an extraordinary effort that should produce the maximum result compatible with exactness, grew into a purpose with me, and a method was tentatively elaborated and perfected which gave the result mentioned above, without being in the least degree irksome to any of the participants, since they all accepted the idea with eagerness.

It seems rather extraordinary now, after this accumulated weight of years, but it was pure enthusiasm with all of us then, free from any taint of vainglory or disregard of the rigorous requirements of orthodox observing. The idea simply was to demonstrate what four carefully trained specialists in this kind of work, acting in perfect accord, could accomplish with our Meridian Circle in a given time.

The programme required the presence of three men in the circle room: The observer, who reclined in a comfortable position upon the chair throughout the observations; the microscope reader, who also made the pointings of the telescope; and the recorder, temporary chief of the party, who was seated at a small desk before the dial, and whose duty it was to give out the settings from the programme, record the readings of the microscopes, take their means, and give such information to the observer as was needed to identify the star.

In this arrangement, the greatest physical strain fell upon the one at the miscroscopes, and consequently the recorder exchanged places with him at intervals of an hour and a half. When the night was a long one (eight hours), the observer for the second half came at midnight, and thereafter the first observer would alternate with the recorder and miscroscope reader. Each observer began and ended with a time star, and observed others at

* As a means of comparison, the catalogue of the Royal Observatory of the Cape of Good Hope, which contains 40,000 observations of 12,441 stars may be taken. This was observed by Mr. STONE with the aid of four assistants, in eight years (1870–78), and was the most notable production up to that time.

intervals of an hour. Barometer and thermometer readings were taken hourly throughout the night. Six circumpolars,.at least, three at upper culmination and three at lower, were always observed upon a long night, and three nadir, level and collimation determinations were made. Readings were also made upon the south collimator at the beginning and end of the work, to serve as a check upon the azimuth in case the last pair of circumpolars should be lost by clouds.

The routine from beginning to end of the night—twilight to twilight—was practically uninterrupted; the chronograph was never suffered to run down, and I could easily substitute a new sheet while the cylinder was making one-third of a revolution. Usually, however, two sheets, corresponding to four hours' work, were fastened upon the barrel at a time, and it was then the work of a few seconds only to strip off the upper one. During the day, the transits—more than 4000—upon the chronograph sheets were read off, the stars were identified and the observations were recorded, and a new programme was arranged for the coming night. The basis of the programme was our Zone Catalogue, of course, but all the anonymous stars of which the observer gave any note during the observations were also incorporated.

The above was the rigorous procedure during the month of December, not omitting readings for runs and any other desirable operation that could be performed in daylight. During all this time there was neither strain, nor hurry, nor fret over a failure, but every operation was in the charge of an assistant who knew how to do it well in the least possible time. The longest nights were those of December 23, 24, 25 and 26—32 hours in all—aggregating 1549 complete determinations. The gentlemen who assisted me were Messrs. BACHMANN, DAVIS and STEVENS, but in the circle room there was no distinction of person and we alternated according to rule. I had employed the same method during the four preceding months, also, but in less degree, and by way of practice."

ARGENTINE NATIONAL ORSERVATORY,
CORDOBA, June 24, 1891.

GIFT TO THE LICK OBSERVATORY FROM PROF. MICHELSON.

In Vol. III of the *Publications* (page 274) Prof. MICHELSON describes an apparatus devised by himself for making measures of very small angles by interference methods and gives observations

of the diameters of *Jupiter's* satellites made by himself during the summer of 1891 with such an apparatus applied to our 12-inch equatorial.

Since that time Prof. MICHELSON has had a similar device constructed by WARNER & SWASEY to fit the 36-inch telescope, with which it is hoped to measure the diameters of some of the smaller satellites, and of some of the asteroids. The apparatus is now completed and has been presented to the observatory through the kindness of Prof. MICHELSON. E. S. H.

December 25, 1891.

HANDBOOK OF PRACTICAL OPTICS BY STEINHEIL & VÖIT.

[*Handbuch der Angewandten Optik* von Dr. A. STEINHEIL und Dr. E. VOIT, Band I, pp. 314 (Leipzig, 1891.)].

Messrs. STEINHEIL & VOIT need hardly have remarked in the preface to their recently published *Handbuch* that the work was the outcome of thirty years' experience in grinding lenses. For whether the reader approve their methods or not, he must see that these bear the stamp of practicability. We have before us a product of this well-known Munich *atelier*, which gives ample evidence that if lens grinding be an art, it is also *more* than an art.

The interested readers will be rather the users than the makers of telescopes; for, though the work is professedly written for the latter class, it contains general methods, illustrated by many special cases, for computing, with great accuracy, the efficiency of a lens either as regards its correction for color or spherical aberration, its definition, distortion, fulfillment of Gaussian condition, flatness of field, etc. What strikes one most in this treatment is perhaps the rigidity of the methods employed. There is a refreshing absence of approximations; focal lengths are never measured save from principal points; thicknesses of lenses are never disregarded; the air-space of separation in double objectives receives its full share of attention.

A rigid adherence to a clear and simple notation adds immensely to the lucidity of the discussion. To feel the importance of this, one has only to recall that in a corrected glass there are three media each with its own refractive index and thickness, besides four refracting surfaces each with its own radius, its own angles of incidence and refraction. The notation adopted is that of SEIDEL in which the successive *surfaces* and quantities asso-

ciated with them, have for subscripts the successive *even* numbers; while the *media* in order are marked by the *odd* numbers. Constants are connoted by small Latin letters; points, by German capitals; lengths, by Latin capitals; angles, by small Greek letters, each carrying the subscript of its own refracting surface.

The first three chapters, devoted to reflexion, refraction and the Gaussian cardinal points, have nothing to distinguish them from the ordinary text-book treatment. Indeed, we are surprised to find that the only method recommended, or even mentioned, for the determination of refractive indices is one which must be considered decidedly inferior. If the search be for the sixth decimal of a refractive index, one can hardly hope to find it by allowing the parallel beam which leaves his collimator to divide on the refracting edge of the prism, and by then measuring the divergence between the two beams which are simultaneously reflected from the two faces of the prism: for one has no guarantee, ordinarily, that the beam furnished by one-half the collimator objective will have an identical direction with that furnished by the other half. We venture to suggest the use of the Gaussian eye-piece in the view telescope, thus measuring the divergence of the two normals to the prism-faces, as being the most accurate method in use. Here but one objective is employed and that with full aperture, while for delicacy of setting one can scarcely exceed the coincidence of a fine pair of cross-hairs with its "ghost."

The remaining chapters are peculiarly the authors' own. In them, single and double objectives are discussed in great detail. The general method of the writers is to compute a series of lenses, each of the same linear aperture and focal length, but each member of the series differing from its neighbor in some small degree; say in the distribution of refraction between the surfaces of the flint, perhaps in the thickness of the air-space, or possibly the flint instead of the crown may be turned so as to face the incident beam, etc. Each of these changes of condition produces a change in the character of the image, which latter the author is thus enabled to discuss in a purely inductive manner.

If, for instance, a reading telescope be desired, where the all important condition is that spherical aberration be eliminated for divergent as well as for parallel light, the designer has only to run through the series and pick out that form (all forms not workable are excluded), for which the spherical error is least, provided, of course, that the glass is reasonably corrected in other respects.

From the tables having dispersions and refractive indices for arguments, a color curve for any ordinary lens might be easily predicted. In this connection, to be sure, the want of homogenity in commercial glasses might have been touched upon. Irregularities of this kind justify Sir HOWARD GRUBB in his remark that "*object-glasses cannot be made on paper.*"

On page 184, we have a sample of what may be hoped for in the second volume, *viz.*, some general considerations regarding the choice of lens for any particular work; in other words, a weighting of the different corrections for various lines of work.

The pages of the first volume, interesting as they are, might have been considerably enlivened by bringing the discussions of the above type into closer juxtaposition with the mathematical treatment.

While the work, as it stands, is far from arid, one might easily finish its reading with the impression that all the errors mentioned were of equal importance. The appearance of the next part is expected with pleasure. HENRY CREW.

ON VARIATIONS OF SHORT PERIOD IN THE LATITUDE* [BY SIR WILLIAM THOMSON, PRESIDENT R. S.].

NOTE: At the anniversary meeting of the Royal Society of London, November 30, 1891, Sir WILLIAM THOMSON presided and delivered his annual address. An abstract of the address is given in *Nature* for December 3. From this abstract the following paragraphs are taken.

"A fundamental investigation in astronomy, of great importance in respect to the primary observational work of astronomical observatories, and of exceeding interest in connection with tidal, meteorological and geological observations and speculations, has been definitively entered upon during the past year, and has already given substantial results of a most promising character. The International Geodetic Union, at its last meeting in the autumn of 1890, on the motion of Professor FOERSTER, of Berlin, resolved to send an astronomical expedition to Honolulu, which is within 9° to the opposite meridian to Berlin (171° west from Berlin), for the purpose of making a twelve months' series of observations on latitude corresponding to twelve months' analogous observations to be made in the Royal Observatory, Berlin. Accordingly Dr. MARCUSE went from Berlin, and, along with Mr.

* See *Publications* A. S. P., vols. II, p. 135, III, p. 254.

PRESTON, sent by the Coast and Geodetic Survey Department of the United States, began making latitude observations in Honolulu about the beginning of June, 1891. In a letter from Professor FOERSTER, received a few weeks ago, he tells me that he has already received from Honolulu a first installment of several hundred determinations of latitude, made during the first three months of the proposed year of observations; and that, in comparing these results with the corresponding results of the Berlin Observatory, he finds beyond doubt that in these three months the latitude increased in Berlin by one-third of a second, and decreased in Honolulu by almost exactly the same amount. Thus, we have decisive demonstration that the motion, relatively to the earth, of the earth's instantaneous axis of rotation is the cause of variations of latitude which had been observed in Berlin, Greenwich, and other great observatories, and which could not wholly be attributed to errors of observation. This, Professor FOERSTER remarks, gives observational proof of a dynamical conclusion contained in my Presidential Address to Section A of the British Association at Glasgow, in 1876, to the effect that irregular movements of the earth's axis to the extent of half a second may be produced by the temporary changes of sea-level due to meteorological causes.

"It is proposed that four permanent stations for regular and continued observations of latitude, at places of approximately equal latitude, and on meridians approximately 90° apart, should be established under the auspices of the International Geodetic Union. The reason for this is that a change in the instantaneous axis of rotation in the direction perpendicular to the meridian of any one place would not alter its latitude, but would alter the latitude of a place 90° from it in longitude, by an amount equal to the angular change of the position of the axis. Thus two stations in meridians differing by 90° would theoretically suffice, by observations of latitude, to determine the changes in the position of the instantaneous axis; but differential results, such as those already obtained between Berlin and Honolulu, differing by approximately 180° in longitude, are necessary for eliminating errors of observation sufficiently to give satisfactory and useful results. It is to be hoped that England, and all other great nations in which science is cultivated, will co-operate with the International Geodetic Union in this important work."

The United States Naval Observatory.

In the last Report of the Superintendent of the U. S. Naval Observatory at Washington (extracts from which were given in these *Publications*, Vol. III, 1891, page 74), attention was called to the needs of the Institution. The Honorable Secretary of the Navy has given consideration to the subject and his conclusions are stated in the following paragraphs.

[*Extract from the Report of the Secretary of the Navy* for 1891.]

"NAVAL OBSERVATORY.

"The work on the new Naval Observatory has advanced so far that the transfer from the old to the new site will shortly be undertaken. The failure of the contractors has delayed the work of the new building, now in its final stage, but the government is amply protected, and arrangements are now making under the provisions of the contract by which its early completion may be assured.

"When the transfer and installation of the instruments are completed, the government will be in possession of one of the most admirably equipped observatories in the world. The question of the proper administration of this important charge, representing one of the most important branches of scientific investigation undertaken by the government, is one that demands early attention. The system in existence hitherto, by which the selection of the superintendent has been confined to line officers of the navy, subject like other officers to changes of duty at comparatively short intervals, prevents that continuity of administration which is essential in carrying on the work of a great national observatory. No programme of scientific investigation, especially in the department of astronomy, can be carried out successfully by any institution, if liable to frequent interruptions by a change of its administrative head.

"I therefore recommend the adoption of legislation which shall enable the President to appoint, at a sufficient salary, without restriction from persons either within or outside of the naval service, the ablest and most accomplished astronomer who can be found for the position of superintendent.

"I would also recommend, in view of the era of progress and scientific development upon which the observatory is now entering,

that an advisory council be organized, composed of the superintendent of the observatory and its senior professor, and of three other persons of scientific attainments, whose duty it shall be to consider and report upon new instruments and their proper installation; to draw up, with such changes as may be necessary, from time to time, the programme of scientific work, including observation, reduction and publication, and to make such inspections and reports as may be desirable in regard to the character of the work done by the observatory."

With this official encouragement the Astronomers of the United States have very generally signed the following petition to Congress.*

TO THE CONGRESS OF THE UNITED STATES:

"Your petitioners respectfully call attention to the question of the future administration of the new Naval Observatory, as one entitled to your careful consideration. The buildings for this establishment are now being completed on a scale and at an expense which, we believe, have never been equaled in the case of any national institution devoted to celestial research. The magnitude of the appropriations made by four successive congresses for this purpose clearly expresses the popular will that the astronomical observatory of the nation should be second to none in the value and interest of its work.

"We therefore respectfully set forth the fact that buildings and instruments are not the chief conditions of success. A well-considered plan of work, pursued with zeal under competent scientific direction, is absolutely essential. A body of the ablest astronomers, thrown together without adequate guidance, without any problem to solve, and without a concerted plan of work, can no more achieve success than an army can march and fight without a general. All experience shows that the success or failure of a scientific as of a business institution depends upon its directing head.

"By the labors of many generators of investigators, astronomy has now become a science of such extent that those only who make its cultivation the principal business of their lives can keep pace with its progress, and decide how the energies of a corps of astronomers should be directed.

"The proper administration of the observatory now being

* This petition was signed by all the Astronomers of the Lick Observatory.

completed, therefore, requires that its direction should be placed in the hands of a practical astronomer, and we respectfully ask for such legislation as will secure this end.''

It is to be hoped that some action in this very important matter will be reached during the present session, and those members of the A. S. P. who are interested can do valuable service by writing to their Senators and Representatives in Congress setting forth the reasons why such action is desirable. E. S. H.

"A Meteoric Crater.

"Flagstaff (Arizona), Nov. 30, 1891.

"G. K. Gilbert and Marcus Baker, the former being Chief Geologist of the U. S. Geological Survey, have returned from the Cañon Diablo, where they were sent by the Government to make a map of the region where so much meteoric iron has recently been found.

"They spent sixteen days investigating the mammoth hole in the ground supposed to have been made by a meteor. This hole is 625 feet deep and two and one-eighth miles in circumference.

"The theory is, from the appearance of the walls and from the fact that there have been found many pieces of meteoric iron around the hole, that the meteor penetrated the earth to a depth of 700 or 800 feet before it exploded, and this accounts for the strange phenomenon.

"Three pieces of the meteor, weighing 300, 600 and 850 pounds, respectively, were found on the *mesa* within two miles of the crater and are now in the Smithsonian Institution. Besides these, they found many pieces weighing from two ounces upward.—Telegram to the San Francisco *Examiner*, Tuesday, December 1, 1891.

A Bright Meteor.

Nordhoff, Ventura County, California,
November 21, 1891.

E. S. Holden, LL. D., *Mt. Hamilton, Cal.*

Dear Sir: On Wednesday, the 18th inst., at about 10.30 o'clock, P. M., or perhaps a little later, a very strange and unusual phenomenon was noticed by a member of my family and another person, on returning from a concert. A sudden flash of

light, which startled the occupants of the buggy, and frightened the horse attached, was seen moving from southwest to northeast, and then became stationary. The position of persons was in a narrow valley about a mile wide and surrounded by mountains; and this magnificent stream of light (which seemed to eclipse the bright moon-light) appeared to cover from one-fourth to one-third of the horizon. There was a nucleus, at first, which gradually disappeared, after which, at the center of this broad blaze of light there seemed to be a fading away, until a blackish-blue stripe was formed, but the outer edges of the light remained plainly visible for one-half to three-fourths of an hour, or while the horse walked slowly three-quarters of a mile. There was no report as in case of the falling meteoric stone. The parties would be ready to answer any queries you might propound. * * *

H. J. DENNISON.

INSTALLATION OF THE NEWALL REFRACTOR AT THE UNIVERSITY OF CAMBRIDGE.

The great telescope presented by Mr. NEWALL to the University of Cambridge, England, was used for the first time at Cambridge early in October, 1891, by Professor J. C. ADAMS, in an examination of the planet *Neptune*.

It is exactly 46 years since Professor ADAMS, then a student at Cambridge, sent his calculations of its position to the Observatory of Greenwich, and it is 45 years since the actual discovery of the planet at the Observatory of Berlin (September 23, 1846).

DR. RUTHERFURD'S NEGATIVES OF THE MOON.

Through the kindness of Professor REES the Lick Observatory collection of copies of Dr. RUTHERFURD'S moon-negatives has been enriched by three examples additional to those named in the *Publications* (vol. iii, page 373), as follows:

1864, November 10, Age 11 days.
1864, November 13. Age 14 days (2 copies).

I understand that Professor REES is making a study of the original negatives in New York with special reference to the history of Dr. KLEIN'S new crater near *Hyginus*. E. S. H.

Catalogue of Positive Copies of the Original Negatives of *Jupiter* taken at the Lick Observatory in 1890, and now in the Library of the R. A. S.

The copies were made by A. Stanley Williams, Esq., F. R. A. S., and are to be deposited in the collection at the Lick Observatory.

No. for Ref.	Date, 1890.	G. M. T.	Long. of Central Meridian. I. Daily Rotation =877°.90.	Long. of Central Meridian. II. Daily Rotation =87c°.27.	Remarks.
		h. m.	°	°	
1	July 8	21 29 21 30	273°.8 274.4	71°.7 72.3	Shadow of Sat. II on disc. Red spot on p. limb.
2	July 13	21 16 21 17	336.0 336.6	95.9 96.5	
3	Aug. 13	18 28 18 29½	55.7 56.6	162.7 163.6	
4	Sept. 1	17 59 18 0	196.0 196.6	295.4 296.0	Red spot near f. limb.
5	Sept. 8	18 6 18 8	225.7 226.9	271.6 272.8	Remarkably fine specimens —full of detail.
6	Sept. 14	17 9½ 17 12	58.4 60.0	59.0 60.5	Red spot near p. limb.
7	Sept. 21	16 4 16 5	43.5 44.1	351.0 351.7	Red spot.
8	Sept. 22	15 23 15 24	176.4 177.0	116.5 117.1	
9	Oct. 5	15 50	84.5	285.2	Red spot at f. limb.
10	Oct. 6	15 15 15 17	221.0 222.2	54.3 55.5	Red spot near p. limb.
11	Oct. 13	15 5 15 14	242	22	Two images between these times. Red spot.
12	Oct. 13	15 58 16 0	271.5 272.7	51.3 52.5	Red spot near p. limb.
13	Oct. 19	15 25 15 27½	118.1 119.6	211.2 213.7	
14	Oct. 20	15 46 15 50	288.5 290.9	14.9 17.3	Red spot.
15	Oct. 27	15 12 15 13	292.0 292.6	325.1 325.7	Red Spot.
16	Nov. 2	14 47 14 49	142.2 143.4	130.7 131.9	

Ogden, Utah, Nov. 20, 1891.

Dear Prof. Holden: I send this to let you know that clouds so obscured the moon on the evening of the 15th that no observations could be taken of the eclipse.

Very truly yours, W. C. Parmley.

THE ROYAL ASTROPHYSICAL OBSERVATORY OF POTSDAM,* BY ARMIN O. LEUSCHNER.

From time to time there have appeared in these publications pictures of many of the larger observatories of the world with descriptions from the pen of Prof. HOLDEN. Upon my return from Germany this fall, where I visited a number of observatories, Prof. HOLDEN invited me to write an account of the Potsdam Observatory, which I take pleasure in doing. Much of the short account that follows is condensed from Lieut. WINTERHALTER'S Report on European Observatories (see *Publ.* A. S. P., vol. III, page 40). The accompanying wood-cut is copied from the same report with the kind permission of the superintendent of the U. S. Naval Observatory.

During the early decades of the present century most of the observatories of Europe were built or rebuilt. It was natural on every account that they should be placed in the midst of towns and cities near the administrative offices of the Universities or of the governments to which they belonged. The vast industrial progress of civilized countries in the last half of the XIXth Century has brought with it the electric light, heavy traffic in the streets, railways and tramways, and clouds of dust and smoke overhanging all great cities. Thus it is that nearly all the observatories founded or rebuilt in the years 1830-50, as well as many of the older institutions, found themselves in 1870-1880 in very undesirable situations. The transparency of the air was ruined by the dust and smoke, the darkness of the night-sky was lost in the presence of the electric light, and observations of precision, which require a *perfectly* steady foundation, could not be made on sites which were subject to the tremors caused by the passage of wagons, trams and railway cars.

The Royal Observatory of Berlin (founded in 1705, rebuilt in 1835) suffered from the causes just mentioned. It was desired to add to this observatory new departments devoted to astronomical physics, spectroscopy, photography, etc., etc., and it was obvious that such new departments ought not to be located near the parent institution in the midst of a great city. Little progress, however, was made in obtaining the consent and the support of the government until the year 1871, when the late emperor,

* Professor H. C. VOGEL, Director.—*See* the plate, page 24.

FREDERICK WILLIAM, then crown-prince, became deeply interested in the question of founding an observatory such as was desired. Accordingly about 1874, chiefly through his influence, it was determined to found a *Sonnenwarte* (solar-observatory) as distinguished from a *Sternwarte* (star-observatory) near Berlin, and the new establishment was located in the vicinity of Potsdam, the summer residence of German emperors, which can be reached by local train from Berlin in about thirty minutes. The grounds reserved for the observatory comprise thirty-two acres, and these again are bordered by the Royal Parks for which Potsdam is famous and by the grounds reserved for a large geodetic observatory, now in process of construction. The situation is a model one on every account.

The grounds themselves, especially the portions immediately surrounding the observatory buildings and the residences of the director and of the astronomers, are ornamented with flower-beds, lawns, decorative shrubs, trees, etc., and in all respects form a most attractive park. The observatory reservation is easily reached on foot from the Potsdam railway-station in about fifteen minutes. An excellent walk and drive, gently ascending from the city and leading through a wonderful grove of old birch trees, brings us up to a huge gate, the entrance to the grounds. There the wanderer halts bewildered by these high enclosures and that huge gate, through the iron bars of which he discerns at a distance the walls of a grand building shining through dense trees. And had he not already been informed that these walls belonged to the new Astrophysikalisches Observatorium, he might well take them for one of the old castles which remind us of by-gone generations —so completely is this modern structure hidden from our view when we first reach the gate. Yet only for a moment might we thus be misled, for upon having been admitted to the grounds, we at once encounter a modest building of recent origin,—the home of the machinist, who attends to the machinery which furnishes heat, light and water to the observatory, buildings and grounds. On we go and presently find ourselves face to face with a small round building, unmistakably the upper portion of a well. And a wonderful well this is too, for it has a depth of forty-six metres and in it is a little geophysical observatory. At a depth of about twenty-four metres a small observing-room is built into one side of the well, and at various other depths meteorological instruments are suspended. Connected with this well is a moderate-sized

engine-house through which the water from the well is forced up to the highest level on the grounds, namely, to a reservoir located in the tower above the main entrance of the observatory. The engine-house also contains gas-works, which supply a large number of street-lanterns placed in profusion throughout the grounds.

Leaving the well and engine-house and passing the residences of the astronomers, of which the directors' dwelling-house is nearest to the observatory, we reach, after a little walk through shady paths, the main building, the center of attraction in this wonderful home of science. The scope of the observatory was enlarged about 1882 (or at least the enlarged scope was recognized by a change of name) and it is now known as the Astrophysikalisches Observatorium—an observatory devoted rather to researches into the physical conditions of all the stars, than to the astronomy which has to do with merely fixing their positions. The building, consisting of a central body and two wings, is surmounted by three domes, which cover a refractor (objective by SCHROEDER, mounting by REPSOLD) of about twelve inches aperture, an 8-inch refractor by GRUBB (used for observations of solar spots) and a 5-inch refractor by STEINHEIL (used for spectroscopic observation of the sun and for photometric work, etc.). The ground floor of the building contains the laboratories and offices; the basement contains the steam-engine, dynamo, instrument-makers' shop, etc.

In order to secure an even temperature, portions of the roof are covered with sods in which grass is grown, which is a decided novelty in observatory construction, but one which should be effective. Upon entering the building under a square tower, which as was said contains the large reservoir, we find ourselves in a spacious hall running in the direction of the meridian. A marble plate with inscription in gold set in the wall to our left reminds us of the untiring interest taken by the late emperor FREDERICK in giving the world this grand observatory. To the left also are the offices of the director, Prof. VOGEL, and of Dr. SCHEINER, the astronomer. Here it is where these wonderful photographs of star-spectra are scrutinized under the microscope. Here, too, have been written by these eminent astronomers the many astronomical papers dealing with new and important discoveries. Passing through a sort of ante-chamber which is used for photographic purposes, we enter a large apartment containing one of the most beautiful instruments ever constructed for spectrographic investi-

gations,—a spectrometer by BAMBERG admitting of a very high dispersion and especially valuable on account of its excellently constructed micrometer and because of the accuracy of its circle, whose divisions, as Prof. VOGEL assured me, are almost perfect. This instrument is chiefly used on the solar spectrum, the rays of the sun being thrown upon the objective of the collimator in a horizontal direction by means of a heliostat.

There are a great many other instruments in the glass-cases of this room, the most interesting of which is a spectrometer (by SCHROEDER in Hamburg) with nineteen prisms. This instrument has been extensively used in studying the spectrum of the sun. To the left under the large telescope is the clock-room, and in a projection of the building to the south is a heliograph with which photographs of the sun are regularly taken. The heliograph is a fixed telescope of 6.3 inches in aperture and 157 inches focus, into which the sun's image is reflected by a heliostat. (The axis of the Potsdam heliograph is inclined parallel to the axis of the earth; in other respects it is similar in general principle to the 40-foot horizontal photoheliograph of the Lick Observatory.)

To the right of the main hall are an instrument-room and a study for assistants, where on a large table the latest numbers of astronomical bulletins of all countries are exhibited, and in a conspicuous place among these we are pleased to see the *Publications of the Astronomical Society of the Pacific.*

From the main body of the building arched corridors lead to the east and west wings whose towers contain the two smaller telescopes already mentioned. The east tower harbors also a rapidly-growing library. To the north, in front of these wings, various meteorological instruments are exposed. From the domes we step on the roof from which a beautiful view of the surrounding country and cities may be obtained and from here into the big dome with the large equatorial. This instrument has been used for very many important researches and is at present engaged in the determination of the motions of the brighter stars in the line of sight by means of photography. An ingenious addition to the eye-end of the telescope carries the very powerful spectroscope. The spectrum of the star and the comparison spectrum are *photographed* by exposures of from fifteen to sixty minutes, and subsequently enlarged by another ingenious device so as to be suitable for measurement.

The results already obtained for the motion of stars in the line

of sight by these methods are of extreme precision. Together with the *visual* observations made with the same object at Mount Hamilton, they have begun an entirely new epoch in spectroscopic work of the kind, on account of their unexpected accuracy; and they will lead to new and independent solutions of many great cosmical questions—such as the determination of the motion of the solar system in space, etc. The researches at Potsdam and similar ones at the Harvard College Observatory have already led to most unexpected and important discoveries with regard to double stars. There is no space to speak of them here, but a reference may be made to these *Publications*, Vol. II, pages 27, 125, Vol. III, page 46, where some of them are mentioned.

The Observatory at Potsdam proposes to take part in the making of the International Photographic Charts of all the stars down to the fourteenth magnitude and is already in possession of its 13-inch photographic telescope, which has been mounted in a capital way by the REPSOLDS. The mounting differs from that of other telescopes of the same character in having its pier not straight and vertical, but broken, and so that the upper portion is parallel to the axis of the earth. By this arrangement stars near the zenith may be observed on both sides of the meridian without reversing the telescope. In visual observations reversing the telescope is merely felt as a great inconvenience; in continued photographic exposures it is utterly inadmissible.

The telescope is mounted in a small brick structure west of the main building. Some plates have already been obtained with it for the grand chart of the heavens. The telescope is really a double telescope, inasmuch as beside the 13-inch photographic glass, there is mounted in the same tube a 9-inch glass for visual observations, by means of which the plate is guided in long exposures. The most ingenious arrangements for illuminating all required parts of the telescope, as well as the recorder's desk, by means of electricity, have been devised by Dr. SCHEINER and are already in operation. In a small frame building adjoining the dome of the photographic refractor is a transit instrument which is used solely for time observations.

The observatory possesses a great number of auxiliary instruments—photometers, spectroscopes, photographic and meteorological apparatus, etc., etc., which have been used in the researches published in the seven quarto volumes already distributed.

Every Friday afternoon the doors of the observatory are thrown

open to the public. No instruction is given to students of astronomy. Every possible assistance, however, is rendered to those who are already somewhat advanced in astronomical work.

SIR JAMES SOUTH ON CHRONOMETERS.

In 1868 was proved the testament of Sir JAMES SOUTH, the astronomer, giving a pocket chronometer to the EARL OF SHAFTESBURY, to the EARL OF ROSSE, and to Mr. A. J. STEPHENS, "in the full confidence" he observes, "that they would respectively use and wear them in the same manner as I am in the habit of wearing my chronometer—namely, in my pantaloons pocket, properly so called."

PERSONAL NOTE REGARDING PROFESSOR MICHELSON.

"WORCESTER (MASS.), January 16, 1892.

"ALBERT A. MICHELSON, of CLARK University, has been invited by the International Bureau of Weights and Measures to spend the coming summer at the Bureau's laboratory at Breteuil, near Paris, for the purpose of establishing the metric standard in terms of wave-lengths of light. He is asked to make the basis of units of length natural instead of arbitrary.

"This invitation is an honor both to American scholarship and to CLARK University. The invitation of the international committee has been accepted by Professor MICHELSON, with the formal approval of the president and trustees of CLARK University."—Telegram to S. F. *Chronicle.*

DUPLICATES IN THE LIBRARY OF THE LICK OBSERVATORY.

The following duplicate volumes, among others, are in the library of the Lick Observatory. Most of them are neatly and substantially bound.

ARGELANDER: Abo Observations, vols. 1, 2, 3, folio.

BALL: Elements of Astronomy, 1 vol., 16mo.

BERLINER JAHRBUCH: for 1883, 1886–7–8, 4 vols., 8vo.

BODE'S JAHRBUCH: for 1795–6–7–8 and 1800, 5 vols., 12mo.

GOULD: Uranometria Argentina (the text only), 1 vol., 4to.

HERSCHEL and MAIN: Catalogue of Double Stars, 1 vol., 4to.

LAMONT: Catalogues of Stars, 6 vols., 8vo.

LONDON: Memoirs Royal Astronomical Society, vol. 24, 1 vol., 4to.

MADRAS: Observations for 1862–3–4, 1 vol., 4to.

MOSCOW: Observations, vol. ix, parts 1, 2 (1883); x, part 2 (1884); I part 1 (1886). 4 parts, 4to, paper.

NEW HAVEN: Amer. Journal Science, vol. 25, 1883, 8vo, paper.

PARIS: *Annuaire* Bureau Longitudes, 1876–7, 2 vols., 16mo, paper.

RUEMKER: Paramatta Observations (Phil. Trans., 1829), 1 vol., 4to, paper.

TODD: Tables of the Satellites of *Jupiter*, 1 vol., 4to.

WASHINGTON: U. S. Naval Observatory Eclipse Report, 1878, 1 vol., 4to.

We should be glad to exchange these volumes for others which are needed in our library, as for example:

ARGELANDER: OELTZEN'S ARGELANDER'S Northern Zones.

ARGELANDER: The maps (only) to the first section of the DM. (+ 90°, — 2°).

BULLETIN ASTRONOMIQUE: vols. 1, 2 wanted.

GOULD: Astronomical Journal, volume 1.

MOSCOW: Observations—any volumes earlier than 1883.

NATURE: Volumes 1, 2, 3, 4 wanted.

OBSERVATORY: *The Observatory*—the volumes earlier than vol. 9 are wanted. E. S. H.

GIFTS TO THE LICK OBSERVATORY.

We have to thank Mr. J. A. BRASHEAR for the very acceptable present of a ROWLAND concave diffraction grating ruled on speculum-metal with the unusually short radius of 21.6 inches. There are 2887 lines to the inch and the ruling is about 2⅛ inches by 1 inch. Messrs. WARNER & SWASEY have also been so kind as to present the Observatory with two fine screws (with nuts) six inches long, ten threads to the inch, to be used with the photographic enlarging apparatus of the great equatorial.

E. S. H.

MINUTES OF THE MEETING OF THE DIRECTORS HELD IN THE ROOMS OF THE SOCIETY, JANUARY 30, 1892.

President PIERSON presided and a quorum was present, as follows: Messrs. ALVORD, BURCKHALTER, CAMPBELL, HILL, MOLERA, PIERSON, ZIEL. The minutes of the last meeting were read and approved. The following candidates were duly elected:

LIST OF MEMBERS ELECTED JANUARY 30, 1892.

A. B. ALEXANDER	404 Post Street, S. F., Cal.
RICHARD H. ALLEN	Chatham, Morris Co., New Jersey.
W. S. ANDREWS	Edison Building, Broad Street, New York City.
F. R. BISSELL	183 La Salle Street, Chicago, Ill.
W. C. BOUSFIELD	409 California Street, S. F., Cal.
Miss MARY E. BYRD	The Observatory, Smith College, Northampton, Mass.
Miss CAROLINE R. CLARK	Care of Alvan Clark, Cambridgeport, Mass.
CHARLES A. CRACKBON	300 Scott Street, S. F., Cal.
FRANK H. DICKEY	3626 Ellis Avenue, Chicago, Ill.
CHARLES R. EASTMAN	St. Paul, Minn.
GEORGE STUART FORBES	Madras, India.
CHARLES GRAVES	Divinity Hall, Meadville, Penn.
T. P. GRAY	The Lodge, Clapham Road, Bedford, England.
ALVA J. GROVER	1137 Park Avenue, Omaha, Neb.
STEPHEN M. HADLEY	Penn College, Oskaloosa, Iowa.
H. S. HERRICK	13 Nevada Block, S. F., Cal.
JOHN E. LEWIS	Ansonia, Conn
ADOLPH LIETZ	422 Sacramento Street, S. F., Cal.
J. A. LIGHTHIPE	112 Bush Street, S. F., Cal.
MARSDEN MANSON	10 California Street, S. F., Cal.
DAVID MILLER	Lands Department, Sydney, New South Wales.
JAMES MOORE	310 California Street, S. F., Cal.
CHARLES NORDHOFF	Coronado, Cal.
Miss CLARA A. PEASE	High School, Hartford, Conn.
THOMAS PORTER	Lauriston, Ballarat, Australia.
M. REIMAN	4325 Drexel Boulevard, Chicago, Ill.
GEORGE A. ROSS	734 Guerrero Street, S. F., Cal.
JOHN R. RUCKSTELL	320 Post Street, S. F., Cal.
JOSEPH C. SALA	429 Montgomery Street, S. F., Cal.
ROGER SPRAGUE	Berkeley, Cal.
Miss HENRIETTA STRONG	"The Virginia," Chicago, Ill.
Mrs. WM. EMERSON STRONG	"The Virginia," Chicago, Ill.
Professor WM. SYMMONDS	Santa Rosa, Cal.

C. L. TAYLOR	709 Bush Street, S. F., Cal.
Señor ENRIQUE TORIELLO	Consulate of Guatemala, San Francisco, Cal.
Prof. L. W. UNDERWOOD	Underwood Observatory, Appleton, Wisconsin.
Professor L. G. WELD	State University, Iowa City, Iowa.
JAMES A. WILSON	1321 Steiner Street, S. F., Cal.

The resignations of several members were read and accepted.

On motion, the President and Secretary were empowered to make such changes in the diploma as they may deem desirable, and to order 500 copies printed. Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE-HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, JAN. 30, 1892.

The minutes of the last meeting were read and approved.

It was *voted* that the thanks of the Society be returned to the California Academy of Sciences for the use of their lecture-hall.

A list of thirty-eight new members elected at the Directors' meeting was read to the meeting.

A number of presents was announced, and special attention was called to the beautiful colored lithograph of the lunar eclipse of November, 1888, by Prof. WEINEK, of Prague.

The following papers were presented:

a. The Rotation of the Sun (translation from the German of Dr. SCHMIDT), by A. C. BEHR, of Chicago.

b. POGSON'S Comet and the BIELAN Meteors, by W. H. S. MONCK, of Dublin, Ireland.

c. The McKIM Observatory, by Prof. W. V. BROWN, of Greencastle, Indiana.

d. When shall we have Another Glacial Epoch? by GARRETT P. SERVISS, of New York City.

e. The Total Eclipse of the Moon, January 28, 1888, by Prof. WEINEK, of Prague (translated by F. R. ZIEL, of San Francisco.)

f. Lantern Slide Exhibition, with lecture by W. W. CAMPBELL, of Mount Hamilton.

The President announced that a branch of the Society was to be organized in Pittsburg, Penn., similar to the Chicago section.

A committee to nominate a list of eleven Directors and Committee on Publications, to be voted for at the Annual Meeting was appointed as follows: Messrs. JOSÉ COSTA (chairman), F. H. McCONNELL, ARTHUR RODGERS, HARRY DURBROW, EDWARD B. YOUNG.

A committee to audit the accounts of the Treasurer and to report at the Annual Meeting was appointed as follows: Messrs. M. M. O'SHAUGHNESSY (Chairman), OTTO VON GELDERN, F. W. ZEILE.

The hall was darkened, and Mr. CAMPBELL exhibited about seventy-five lantern slides. These included copies of the recent photographs of nebulæ, clusters and the moon taken at the Lick Observatory and elsewhere; diagrams illustrating the principles and methods of spectrum analysis, photographs of famous spectroscopes; and photographs of star spectra; in connection with which the recent spectroscopic observations were reviewed, and the nature of the present problems explained.

The meeting then adjourned.

MINUTES OF THE NINTH REGULAR MEETING OF THE CHICAGO SECTION A. S. P.

The *ninth* regular meeting of the Chicago Section A. S. P. was held Friday evening, October 23, 1891, at the Kenwood Astro-Physical Observatory, Chicago.

Mr. G. A. DOUGLASS presided. The minutes of the last meeting were accepted as read. G. E. HALE then gave an account of a recent visit to various observatories and laboratories in Europe, after which observations were made by the members with the 12-inch telescope.

GEORGE E. HALE, *Secretary.*

MINUTES OF THE TENTH REGULAR MEETING OF THE CHICAGO SECTION A. S. P.

The *tenth* regular meeting of the Chicago Section A. S. P. was held Saturday evening, December 5, 1891, at the Kenwood Astro-Physical Observatory, Chicago.

Mr. G. A. DOUGLASS occupied the chair. The minutes of last meeting were accepted as read. Mr. A. C. BEHR read a translation of a paper on "The Rotation of the Sun," published in "*Sirius*," by Prof. A. SCHMIDT, and supplemented it by a few remarks. Mr. G. E. HALE explained the spectroscopic method used in determining the velocity of the sun's rotation, and discussed various questions raised in the paper. An account was given of a solar eruption of only fifteen minutes duration which was observed simultaneously at Kalocsa, Hungary, and at the Kenwood Observatory, Chicago. Results of recent progress in solar prominence photography were announced, and a description was given of a visit to the "*Urania*," in Berlin. After the adjournment of the meeting the members observed *Jupiter*, the *Orion* nebula, and other objects with the 12-inch telescope.

Application for membership in the A. S. P. and Chicago Section was received from—

Mr. F. R. BISSELL, 183 La Salle Street, Chicago.

GEORGE E. HALE, *Secretary.*

OFFICERS OF THE SOCIETY.

WM. M. PIERSON (508 California Street, S. F.),	*President*
FRANK SOULÉ (Students' Observatory, Berkeley), E. J. MOLERA (850 Van Ness Avenue, S. F.), J. M. SCHAEBERLE (Lick Observatory),	*Vice-Presidents*
CHAS. BURCKHALTER (Chabot Observatory, Oakland), W. W. CAMPBELL (Lick Observatory),	*Secretaries*
F. R. ZIEL (410 California Street, S. F.),	*Treasurer*

Board of Directors—Messrs. ALVORD, BURCKHALTER, CAMPBELL, HILBORN, HILL, HOLDEN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ, ZIEL.

Finance Committee—Messrs. ZIEL, HILBORN, BURCKHALTER.

Committee on Publication—Messrs. HOLDEN, YALE, CAMPBELL.

Library Committee—Messrs. MOLERA, VON GELDERN.

Committee on the Comet Medal—Messrs. HOLDEN (*ex-officio*), SCHAEBERLE, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Messrs. DOUGLASS (Chairman), EWELL, HALE (Secretary), PIKE, THWING.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

36 INCH LICK TELESCOPE

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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. IV. SAN FRANCISCO, CALIFORNIA, MARCH 26, 1892. NO. 22.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, AT THE FOURTH ANNUAL MEETING, MARCH 26TH, 1892.

BY WILLIAM M. PIERSON.

A review of the three years' life of this Society ought to be full of encouragement to all of us. Too often the expectations of the earlier members of a Society, particularly a scientific one, are not realized. Those who join for mutual improvement in the science do not immediately realize their hopes, and those who unite for the love of the novel, frequently fail to have their curiosity gratified. These naturally fall away through the loss of their original interest. But the reverse has been the rule with this organization. The Society has steadily advanced from its feeble beginning, and to-day finds itself a permanent, a practical and a prosperous organization.

Its first meeting had a record of forty members on the roll. At the end of the first year its membership had increased to one hundred and ninety-two. Its second year closed with a list of three hundred and sixty, and its third year, now finished, discloses a total of four hundred and thirty-two, of whom three hundred and eighty-one are active subscribing members, and fifty-one life members.

Considering that the Society is located in a district of the United States peopled by less than two millions of inhabitants, among whom, aside from public observatories, probably not a dozen are possessed of any telescopic appliances, it is indeed remarkable that the Society has on its roll over two hundred local members, all of whom take or feel an active interest in its progress. Indeed, considering the environment of the Society,

it may well be doubted if any purely scientific organization has ever met with such a degree of prosperity.

Remarkable, however, as this growth has been, it ought to be the aim of each of us to stimulate it still farther. The greater the Society, the more widespread its influence and the more valuable its contributions to the cause of science. It has been the aim of the officers of the Society to maintain its publications at the highest standard of excellence. But they constitute the larger part of its expenses. Many scientific papers of great value, many details of discoveries made by the great refractor of the Lick Observatory, and many reproductions of exquisite celestial photographs could and ought to be published did our means justify it. We all can aid in the accomplishment of this desirable result. If each of us would introduce one new member during the coming year, the Society would be enabled to greatly extend its sphere of usefulness and its advantages to science and to ourselves.

From the Treasurer's report you will learn that the Society is on a sound financial footing. The permanent funds, those which we owe to the munificence of Mr. ALEXANDER MONTGOMERY for the maintainance of the ALEXANDER MONTGOMERY Library, and to Mr. JOSEPH A. DONOHOE for the Comet-Medal, are well and securely invested.

The Society owes a heavy debt of gratitude to its Publication Committee, and particularly to its chairman, Professor HOLDEN, for its and his labors in editing the Publications of the Society. It is a class of labor particularly onerous and exacting, performed without compensation and of a quality that is wholly unexceptionable.

In retiring from the Presidency, I desire to extend to all the officers of the Society my sincere thanks for their hearty assistance and courtesy during my term of office, and to the members for their uniform kindness and good will.

The past year has developed a greatly increased interest in astronomical research. The formation of new sections of this Society, the improvement and enlargement of astronomical periodicals, the establishment of new observatories, both public and private, the system of university extension, and above all the dissemination of celestial discoveries in the public press—that most accessible of all educators—have given a marked impetus to the study of Astronomy. The proximity to us of the Lick Observatory with its grand instrumental power and skillful staff of observers,

has served to make its revelations easily and immediately attainable to the public, and largely increased the general interest in the science.

This increasing interest in astronomical research has not been limited to intellectual sympathy alone, but has also assumed the tangible and valuable form of financial aid. I take great pleasure in announcing that Mrs. PHŒBE HEARST, the widow of Senator HEARST, of our State, is about to found several Fellowships in Astronomy at the Lick Observatory, and to provide a permanent fund, the interest of which is to be used to promote the scientific work of that institution.

While the collection and dissemination of scientific discoveries are the principal objects of the Society, it fulfils, nevertheless, another and equally valuable purpose, the instruction of those of us who are merely amateurs: In a wide sense the Society is a school. And yet a school wherein we may all to a greater or less extent be tutors as well as pupils. While the professional astronomer, in possession as he is of the most powerful and refined instruments and methods of observation, can and does contribute vastly more than others to the general stock of scientific knowledge, yet there are none so meagerly supplied with those facilities who cannot furnish something—if not original discovery, yet that which may supplement and confirm it.

The difficulty with those of us who are amateurs, or at least the difficulty that I, as a novice, first encountered in astronomy, was that, after understanding the general outlines of its descriptive department, I was at a loss where to begin or what to do in the way of observation. The temptation to wander over the sky with a telescope is almost irresistible, but as a rule nothing is so profitless. It hardly gratifies the curiosity, for the reason that one is ever lamenting that he does not see more than his lens is capable of revealing.

I shall be pardoned, I hope, by the professional astronomers, who constitute so large and invaluable a part of our Society, if as an amateur I make some brief suggestions in this connection to its amateur members. I make them with the more freedom because, as my predecessor very properly said, "We should not forget that we are a society of amateurs." They are the result of my own experience, and have not been without value. In the hope that they may be of some service to others, let me state them.

Specializing, particularly in Astronomy, is indispensable to any

success by the amateur. First of all, have some inquiry, some object in view. That is the great charm of all scientific investigation, because in pursuing it you can note your progress—an invaluable stimulus to study. If you are provided with optical instruments, devote yourself to some particular field, some particular planet, or, if you have the time for day work—the Sun.

For example, select a region of the sky, say from one to five degrees square, the area being in inverse proportion to the aperture of your telescope. If the portion you decide on be in the vicinity of the equator or ecliptic, select two at opposite points of the heavens,—one for Summer and the other for Winter observation. If near the pole, one would suffice, as it would be visible to you the year round. Make these districts of the sky your special field of observation. Consider that your exclusive domain. Make it a point to observe it on every observing night, whatever else you look at. Use the lowest power of your telescope in sweeping over this field. Familiarize yourself with every object in that region within reach of your lens. Note the magnitudes of all the stars within it, their colors, their arrangement in space, their distances from each other, the presence or absence of any nebulous appearances. Identify every star you can by the aid of your star maps; know them by their names or their catalogue numbers. If you have the means of measuring their distances from each other, do so; if not, make eye estimates. A very little practice will enable one to make fair eye estimates of distances. Ascertain the actual angular distances of such stars within your field as are given in your star maps or star catalogues, and compare them with the visual angle between them as seen in your telescope under a given magnifying power, and you will soon be able by comparison to determine with a fair degree of approximation the distances of other stars whose actual position you may not be able to find otherwise.

Above all things, make notes at once of what you observe, with all the details possible. Trust nothing to your memory. An accurate observation of a single phenomenon may be of great importance. No fact is without value, and your observation may at some time fit into a series which would be otherwise incomplete. Remember that celestial phenomena occur but once, and you may happen to be the only person to have observed that one.

If you will do this, it may be your fortune to be the first to

detect a comet, or, if your field be not too far from the ecliptic, a minor planet; for the motion of the latter is very marked with reference to the fixed stars, and that of the former, unless approaching directly in the line of sight, is quite conspicuous. Or mayhap you may be the lucky discoverer of a new star, always a matter of absorbing interest. And if you succeed in neither, you will still have the satisfaction of knowing more about the particular section of the sky which you have made your own, than any one else who has not done the same.

And so, if you select a planet, or our own satellite, or the Sun, make it your special study, whatever else you may choose to examine. Regard that as your specialty. Scrutinize the changes in its appearance—read all there is to be found about it—examine it with reference to the researches of others, and compare them with your own investigations, and again,—make notes of all you observe.

It is remarkable how much more the professional astronomer can see than the novice, even with the same telescope. And yet it is for the very reason that I have given. The veteran is familiar by long study with the details of the special object of his examination, and therefore detects at once the changes, if any, which have occurred in its appearance. That is the reason why it has been so justly said that astronomical observations depend not so much on the power of the telescope as on the man at the small end of it.

The ardor of the amateur is, however, frequently cooled by the feeling that no results attend his labors. He makes no discoveries; he finds himself treading only in the beaten track of others; his progress in science is unmarked with any appreciable improvement. To such let me say: You are accomplishing much more than you think. You are fitting yourselves to appreciate and comprehend the discoveries of others: you are developing your powers of discernment, and your capacity to accept or criticize the theories which may be based on new discoveries. Above all, remember that, anomalous as it may seem, the failure to discover is frequently as valuable as a discovery.

For example, had you selected for your field of observation that region of the sky where the *nova* in Auriga has just been discovered, even if you had not detected the stranger yourself, you would have been able to render a valuable service to astronomy by demonstrating that until a given night it was not visible, and

thus have been the means of fixing accurately the date of its apparition.

And again, how many have been the sharp discussions as to changes in the lunar surface. Suppose that you had selected the moon as your special field of observation, the fact that you had observed no particular feature on a given region of the moon when seen under all its varied angles of illumination, would be of value in proving the disappearance of some crater or other object which may have been delineated on lunar maps or described by former observers. This kind of negative evidence is of high value.

If you possess no optical appliances whatever, but have taken an interest in photography, you can render an efficient service to Astronomy by photographing as frequently as you are able some particular region of the celestial sphere. An examination of your plates from time to time may reward you with like discoveries. Indeed, the photographic plate, when properly exposed, has surpassed the greatest telescope in its revelations. Again, I say, note accurately the time at which your plates are exposed, and the length of exposure. Compare them frequently, and record any apparent changes.

And here let me say that the climate of California is peculiarly adapted to observational and photographic Astronomy. In the great valleys the nights are almost uniformly clear from May to November, and the winter and spring evenings, when not clouded are exceptionally fine. I have no data as to the number of observing nights in those localities, but in San Francisco I have kept a record since October, 1888. Even in that place, so much abused for its summer fogs and winter rains, there is a considerable majority of the nights free from fogs and clouds. Out of 1253 nights, I have a record of 1182; of these, 645 were unobscured by cloud or fog, and 537 obscured. Many of them were first-class observing nights, in which the highest power of the telescope could be used with advantage, and the remainder of the 645 were more or less satisfactory with lower powers.

But you may have neither optical or photographic apparatus, nor the opportunity or taste for observation, Then consider the fertile field which yet remains in the department of theoretical astronomy. I do not mean that we should indulge in mere conjecture or speculation. That is pernicious and idle to the last degree. But the collation and examination and testing the ob-

servations and data of others, and the working out of theories and hypotheses is both instructive and interesting.

When we consider that the very foundation stones of planetary astronomy,—the three immortal laws of KEPLER,—were the results not of observation but of reasoning from the observations of others, and that the "harmonic law" itself was but a long-continued attempt at guessing the proportions between the periods and distances of the planets; that the result when attained was to him based on no principle, and, until the time of NEWTON, wholly arbitrary, we may be encouraged to think that there are other laws and other phenomena which might yield to the same class of inquiry if earnestly pursued.

Take up one of the hundreds of unsolved problems and mysteries of the celestial universe. What is the Zodiacal light, the Gegenschein, the Aurora Borealis, the solar corona, the substance of comets? Why do the planets rotate on their axes; what is the law governing that rotation? Why are the orbits of the planets inclined to the ecliptic if the nebular hypothesis be sound? Why are the axes of the planets inclined to their orbits? Why do the different portions of the Sun's and *Jupiter's* surfaces rotate in different times? Why are there periods of maximum and minimum sun-spots?—and scores of other riddles which Nature, the Sphinx, addresses to us. Mass your reading on the problem you take up. Study all the observations at command. Frame your theories. See how they meet all the facts. Do this, and I assure you that you will find the pursuit as fascinating as it is instructive. If you arrive at a conclusion which seems to you to amount to a working hypothesis, communicate the result to the Society. Let it lead to debate, discussion. Out of it will come your own improvement in the science, and the instruction of us all.

A word of caution, and I have done. The enthusiasm of the amateur is boundless. It is well that it is so. Do not conclude, however, that the first dip into astronomy enables us to discuss the complex problems of the sky with the veterans in science. Be not too eager. Do not expect to discover a planet or a comet the second night you observe, nor hope to expose a fallacy in the law of gravitation on the first examination. Patience is genius. As the master painter said when asked the secret of his art, "I mix my colors with my brains," so do you mix patience with your observations, and conservatism with your reasoning.

In all your work, whether you have much or little opportunity

for it, remember that in science the future is richer than the past. Valuable as have been the treasures extorted from reluctant Nature, those yet to be rifled from her storehouse will far surpass them. Be one of those who, like Sir JOHN HERSCHEL and his two friends, recorded a vow to "do their best to leave the world wiser than they found it."

HARVARD COLLEGE OBSERVATORY ASTRONOMICAL EXPEDITION TO PERU.

BY MRS. M. FLEMING.

It is impossible at any one spot on the surface of the earth to establish an observatory at which all the stars in the sky can be observed. Even at the equator where all stars are visible, accurate measures could not be obtained of the stars in the vicinity of the poles since they are too near the horizon. Thus at the Harvard College Observatory while the horizon is in declination $-47° 37'$, stars south of $-30°$ cannot be satisfactorily measured, neither can good photographs of them be obtained. Several important investigations which are described below having been undertaken at Cambridge and satisfactorily completed for the northern heavens, it was considered of great importance that these researches should be extended to the southern sky. Plans were therefore made for an auxiliary observing station in the southern hemisphere, and they have finally resulted in the erection of a collection of buildings, consisting of a dwelling-house for the observers, and various shelters for the different instruments, about three miles northwest of Arequipa, Peru, at an elevation of about 8000 feet. Here all arrangements have been made for extending to the south pole the researches begun at Cambridge.

The results of the first investigation undertaken as a memorial to Dr. HENRY DRAPER are contained in the H. C. O. *Annals*, Vol. XXVI, part I and Vol. XXVII. The first of these volumes contains a catalogue of the photographs of the stars taken at Cambridge and at Willows, California, and a discussion of the results of the measures made from these plates. The measures themselves form the DRAPER Catalogue of Stellar Spectra and are contained in Vol. XXVII. The photographs were taken

with the BACHE telescope whose objective is a photographic doublet having an aperture of eight inches and a focal length of forty-five inches. A prism having a refracting angle of 13° was placed in front of the objective and thus the spectra of all stars in the field of the telescope were obtained on the photographic plate. The plates used were the most rapid 8 × 10 SEED plates, and each plate covered a region 10° square. Nearly the entire sky north of —30° was photographed here, four different investigations having been undertaken with the above-named instrument. *First*, chart plates having 10^m exposure; *second*, chart plates having 60^m exposure; *third*, spectrum plates having 10^m exposure; and, *fourth*, spectrum plates having 60^m exposure. The spectrum plates having 10^m exposure were those measured for the DRAPER Catalogue. They show the spectra of nearly all the stars brighter than the sixth magnitude. When the last two investigations mentioned above were nearly completed the instrument was removed to California, where it was mounted at Willows and used in photographing the Solar eclipse of January 1, 1889. The photographs obtained with the BACHE telescope in the northern hemisphere being so satisfactory, it was decided that the investigations undertaken with it should be extended to the south pole. Accordingly, in the spring of 1889, an expedition under the direction of Mr. S. I. BAILEY, started for Peru. Owing to the scarcity of wood in that country two frame houses were constructed here, one for the shelter of the instruments, the other for the observers. These were successfully erected on a mountain (since then known as *Mount Harvard*) about 6500 feet high, near Chosica, and about twenty miles east of Lima, Peru. The observers were thus almost entirely cut off from communication with the world below, and all supplies, even including water, had to be carried by mules from the valley below, a distance of about eight miles. The photographic work at this station was similar to that of the Cambridge station, except that the portion of the heavens to be photographed was from — 20° to the south pole. In other respects the plans for the four investigations described above were the same. The weather proved entirely satisfactory during the first six months. Fogs and clouds which often covered the adjacent valleys and the city of Lima did not reach to the top of the mountain. About thirteen hundred photographs were obtained and each of the four principal researches described above was one-half completed. The rainy season then set in,

and during it the observers visited other points of the coast, going as far south as Valparaiso, to look for a better location. After visiting many different places they decided that the climatic conditions at Arequipa, which is situated on the Mollendo railway, at an elevation of about 7500 feet, were the most favorable for the continuation of the work planned for the southern station.

In addition to the photographic work another investigation was conducted at the station on Mount Harvard. All the stars north of $-30°$ of the magnitude 6.0 and brighter, as also the stars brighter than the tenth magnitude used for comparison with variables, and the zones used in the photometric revision of the *Durchmunsterung* were measured at Cambridge with the meridian photometer. When Mr. BAILEY went to Peru he took this instrument with him in order to extend the above investigations to the south pole. He obtained 217 series of observations containing 98,756 photometric comparisons of about 8000 southern stars. This work, together with the results published in Vol. XIV and XXIV, will furnish photometric magnitudes of stars as bright as the ninth magnitude in all parts of the sky. The stars selected for measurement in Peru include all those of the sixth magnitude and brighter south of $-30°$ and all known stars in a series of zones 20′ wide at intervals of 5° in declination from $-25°$ to $-80°$, also all known stars south of $-80°$ and a miscellaneous list of variables, etc. The reduction of these observations is nearly completed and their publication will be begun shortly. While looking for a better location for the southern station, Mr. BAILEY took with him the meridian photometer, and obtained some valuable observations with this instrument at Pampa Central, in the Desert of Atacama, which was selected for the dryness of its climate. In October, 1890, the instruments on Mount Harvard were again dismounted and conveyed to Arequipa.

Photographs of planets, double stars, clusters, nebulæ and other objects of special interest had meanwhile been obtained with the 13-inch BOYDEN telescope at Cambridge and at Mt. Wilson in Southern California. Another expedition was accordingly planned which provided for the removal to Arequipa of this telescope with several smaller instruments. On December 20, 1890, Professor WM. H. PICKERING sailed from New York for Arequipa, Peru, accompanied by his assistants, Mr. A. E. DOUGLAS and Mr. R. D. VICKARS. They joined Mr. BAILEY

at Arequipa, Professor WM. H. PICKERING assuming charge of the station while Mr. BAILEY, having completed his observations with the meridian photometer, returned to Cambridge, bringing with him that instrument and leaving the BACHE photographic telescope where it is still used in completing and extending the investigations described above. Very favorable accounts of the atmospheric conditions at this station have been received. The sky is nearly cloudless during the greater part of the year, the air is remarkably steady, the images of the stars are small and round, and even using high powers, the fluctuations of the images are very slight. Several diffraction rings are visible around the brighter stars. They are rarely seen at Cambridge with so large an instrument. Therefore, at this station, the limit of observation will depend on the size of the instrument used instead of, as at other observatories, the condition of the air. It therefore seems to be of great importance to astronomy to have at this station a large and powerful telescope, one which would give results for the southern heavens, which would be comparable with those of the northern heavens, obtained with the LICK telescope. The BOYDEN telescope has an aperture of only thirteen inches, and yet it is apparently the largest refracting telescope in use in the southern hemisphere, or in fact south of $+35°$. In addition to the study of the objects of special interest mentioned above, a plan has been made for photographing with this instrument, the spectra of all the brighter stars in the southern heavens by placing in front of the object-glass one of the prisms which was formerly used with the 11-inch DRAPER telescope. Photographs have been obtained at Arequipa showing the extreme ultra-violet lines including a series of lines or bands of even shorter wavelength. Thus the detailed study and classification of the brighter stars, also, will be extended to the South Pole. In fact, almost all the more important investigations undertaken at Cambridge are, by means of this valuable auxiliary station, being rapidly extended from pole to pole. Meteorological instruments are in operation at this station and will furnish interesting records of atmospheric conditions prevailing at this elevation. A series of meteorological observations at Vincoucaya, elevation 14,600 feet; at Peru, elevation 12,500 feet; and at Mollendo, near the sea level, have also been obtained. An ascent of El Misti, which has an elevation of 18,600 feet, was made by Professor WM. H. PICKERING.

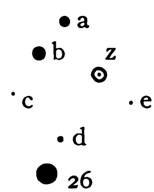
Another interesting expedition was that to *Tiahuanuco* and the sacred islands of Incas, on lake *Titicaca*, which led to results of much archæological interest. Important aid has been rendered to the expedition by many residents in Peru without whose assistance the establishment of the station would have been extremely difficult.

HARVARD COLLEGE OBSERVATORY,
CAMBRIDGE, MASS., February 19, 1892.

ASTRONOMICAL OBSERVATIONS.

Made by TORVALD KÖHL, at Odder, Denmark, in the year 1891.

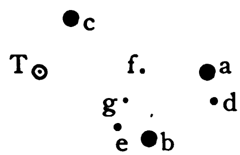
Z Cygni.



The region near the star 26 *Cygni* has been reviewed. December 7, 1890, the star Z appeared as bright as a, but it very rapidly decreased, so that on

January	1 :	Z < c.
"	6 :	id.
"	9 :	id.
February	4 :	Z invisible in the 3-inch STEINHEIL, power 42
"	13 :	id.
"	27 :	id.
August	26 :	Z = b.
"	30 :	id.
September	4 :	a > Z < c.
"	8 :	Z = c.
"	23 :	Z < c.
"	29 :	Z = e.
October	26 :	Z invisible.
November	5 :	Z < e, extremely faint.
"	28 :	id.

T Ursae Majoris.



This variable has been observed at the following times. On December 7, 1890, the star was invisible, but it must have rapidly grown brighter, the maximum being calculated to fall on February 1, 1891.

February	4 :	T a little fainter than a.
"	13 :	a > T > c ; T perhaps a little brighter than b.
"	17 :	id.
"	26 :	id., b almost = c.
March	9 :	id.
April	3 :	T a little fainter than d.
September	10 :	T almost invisible, fainter than g.
"	23 :	e < T < d.
"	24 :	id.
"	29 :	T = d.
November	6 :	T > a. N. B.
"	28 :	T = b.

In "*Publications* A. S. P.," Vol. III, No. 15, page 101, I directed attention to a little star (15) near 61 *Cygni*, which twenty years ago was seen by Professor RUDOLPH FALB, and at the present time is not brighter than 13½ magnitude. I have often looked out for this little star thinking it might reappear as a star of the 11th magnitude, but without success. Many other parts ot constellations, where variable stars were supposed to be situated, have also been reviewed, the region around TYCHO'S *Stella nova Cassiopeiæ*, for example.

The Solar Eclipse of June 6.

This partial eclipse, which, on account of the bad weather could not be observed at the Observatory of Copenhagen, was seen here in the following phases:

h. m. s.		
At 5 38	P. M.	(time of Copenhagen), the eclipse begins about in the middle of the N. W. quadrant.
6 0	"	The disc of the moon is crossing the sun's disc in the north point of the latter.
6 11 15	"	The limb of the moon is touching a large sun-spot in the position $\triangle\alpha = +0.8'$ $\triangle\delta = +6.0'$
6 30	"	Maximum of the eclipse (0.4).
6 47 30	"	Emersion of the above named sun-spot.
7 0	"	At this moment only 0.14 of the sun's diameter is darkened.
7 14	"	End of the eclipse.

At the middle of the observation the sun's altitude was about 14°, and the limit of the moon therefore was very undulating.

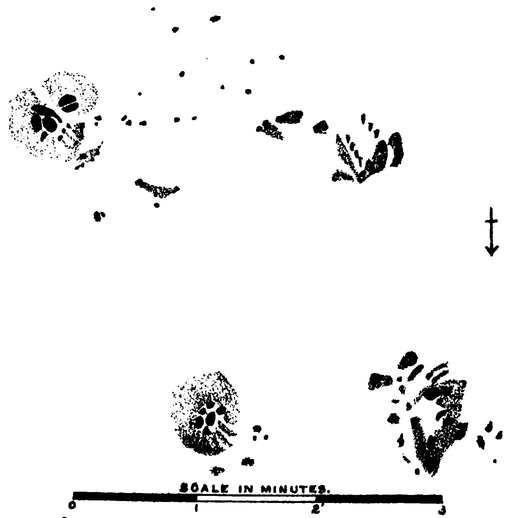
The Lunar Eclipse of November 15.

h. m. s.		
11 25	P. M.	The shadow is touching the eastern limit of the moon in 22° northern latitude.
11 32	"	The shadow crossing *Aristarchus.*
11 36	"	The shadow touches the southern wall of *Grimaldi.*
11 44	"	The shadow through *Copernicus.*
11 45	"	The shadow through *Plato.*
11 47	"	The shadow through *Archimedes.*
11 54	"	The shadow has reached the eastern wall of *Aristoteles* and *Eudoxus.*
11 59	"	The shadow crossing *Bessel, Menelaus* and *Thebit.*
12 4	"	The shadow is passing *Posidonius, Plinius* and the eastern wall of *Tycho.*
12 5 30	"	The shadow is passing the western wall of *Tycho.*
12 11	"	The shadow through *Proclus* and the western wall of *Clavius* and *Theophilus.*
12 27	"	Totality of the eclipse.

No further observations possible, as heavy clouds were crossing the sky.

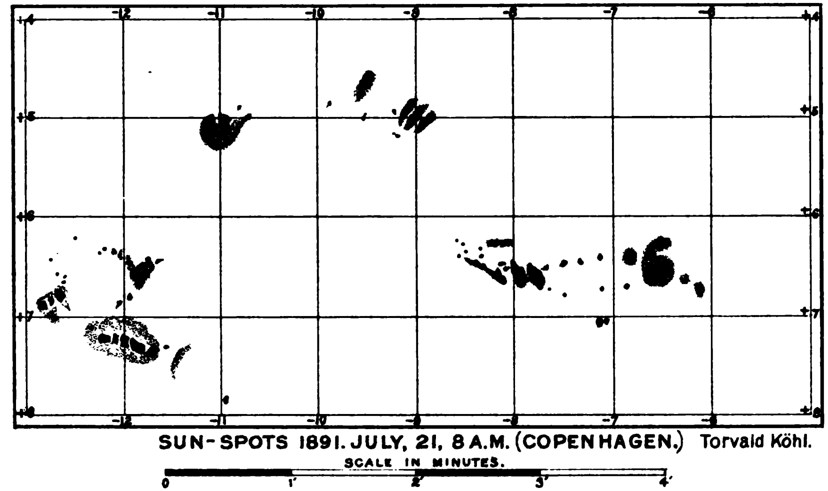
SUN-SPOTS 1891. FEBR. 19 2.30 P.M.

2.



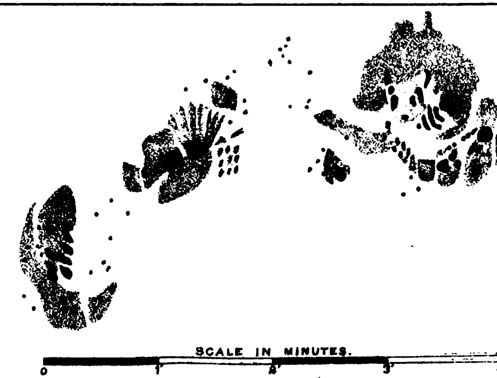
SUN-SPOTS 1891. JULY, 13, 7. A.M.

3.



SUN-SPOTS 1891. JULY, 21, 8 A.M. (COPENHAGEN.) Torvald Köhl.

4.



SUN-SPOTS 1891, SEPT. 5. 3.30 P.M.

Sun-Spot Observations,

On the following days the sun has been observed:

January 6, 14, 18.

February 9, 12, 13, 15, 16, 17, 18, 19, 24, 26, 27, 28.

March 2, 7, 17, 18, 19, 21, 22, 26, 31.

April 3, 4, 5, 6, 9, 10, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29.

May 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 18, 19, 23, 24, 25, 27, 28, 29, 30, 31.

June 1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 20, 21, 22, 29, 30.

July 1, 6, 8, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31.

August 1, 3, 5, 6, 7, 8, 9, 10, 12, 15, 16, 17, 19, 21, 22, 24, 26, 28, 29, 30, 31.

September 2, 3, 7, 9, 11, 13, 14, 19, 23, 24, 25, 27, 29, 30.

October 1, 3.

A number of (44) sketches has been made and positions of a great many sun-spots obtained. In fig. 3, the numbers at the edge indicate differences of R. A. and Decl. in parts; the sun's diameter being divided into 40 parts.

Meteors.

No.	Time.	Beginning.	End.	Magnitude.	Notes.
	h. m. s.	° °	° °		
1	Feb. 4, 8 6 0	167 + 34	182 + 36	2	Slow.
2	Aug. 11, 10 20 0	255 + 42	272 + 27	1	
3	" 34 0	313 + 30	290 + 15	1	
4	" 38 30	262 + 15	262 + 5	1	
5	" 44 0	315 + 34	300 + 24	2	
6	" 56 0	311 + 37	297 + 27	2	
7	" 58 15	354 + 18	347 + 7	2	
8	" 11 2 0	338 + 23	323 + 10	3	Train.

Cloudy weather troubled the observations, which were planned in connection with station Copenhagen, on the 9th, 10th and 12th of August. Occasionally, while observing WOLF'S comet on September 8, a bright shooting star happened to cross the field at 9^h 50^m. The comet was about 1° S. E. from 64 *Pleiadum.*

In the year 1891 a number of (13) fire-ball observations from different places in Denmark has been registered.

HOW TO FIND CELESTIAL OBJECTS WITH AN EQUATORIAL TELESCOPE WITHOUT THE AID OF A SIDEREAL TIME-PIECE.

By Charles Burckhalter.

About nine years ago, when a most enthusiastic student of astronomy, I devised a method which is both simple and efficient for finding invisible, or, to me, unknown objects with an equatorial telescope without the aid of a sidereal time-piece. Having never seen this or any similar method in print, I then believed it to be new, but, as it will be useful to many members of this Society who have equatorials but are without sidereal timekeepers, I will briefly, and as simply as possible, describe the method. By a few trials it will become so familiar that sidereal time is quite unnecessary when we merely wish to find some object whose right ascension and declination are known—in fact, I use it to this day at the Chabot Observatory, rather than go to the trouble of going down a long flight of stairs and carrying up the chronometer, using the sky instead.

At the time of which I write, I found myself the happy possessor of a very fair 4-inch alt-azimuth telescope, which I immediately converted with my own hands into an equatorial without driving-clock or circles—the first equatorial mounting I had ever seen. I had provided myself with "Burritt's Geography of the Heavens" and that invaluable little book "Webb's Celestial Objects for Common Telescopes" (a number of copies of both may be found in the Society's library) and I enthusiastically resolved to carefully observe every object mentioned within the power of my telescope. But, alas! I found that to "resolve" was one thing, and to *find* the objects was quite another.

For prominent financial reasons I did not provide myself with a transit and clock, and my text-book star-maps were found to be practically useless, and, no matter how hard I tried to deceive myself, I was plainly in a dilemma. However, the stars appeared to wink at me as kindly as ever, and I soon found a way out of the difficulty. Hour and declination circles were a necessity, and, as I could not afford to have them made, I determined to construct a pair of circles myself. My first circles were very rude; they were made of stiff card-board; and, while they could not

claim relationship to the elaborate affairs we find with well-mounted equatorials, they placed the sky at my command, and no circles could do more.

I first marked off an 8-inch declination circle, which I carefully divided into single degrees, the space between marks being about one-fifteenth of an inch; every fifth degree was represented by a longer mark, and every tenth degree by a mark with a dot at the end toward the center of the circle. The time-circle was divided in the same manner, each division corresponding to four minutes of time, the twenty-minute and the hour-marks being drawn and marked with greater prominence. These were attached to the bearings carrying the polar and declination axes, and a "pointer" was attached to each of the axes.

I will now give a few examples of how to use the circles, using only well-known and easy objects—the easier the better, in the firm belief that anything new to the beginner cannot be too plainly described.

For our first example we shall take the great nebula in *Orion*. Of course we can find this well-known object without any aid whatever, but it is just as good for our first illustration as though it were the most difficult object to find in the sky. Having determined that this is the object we wish to find, we refer to "WEBB'S Celestial Objects" and find its right ascension to be 5^h 29^m and the declination 5° 28′ south. We next take some well-known object *near by*, let us say *Rigel*, and we find that WEBB gives the R. A. as 5^h 9^m and the declination as 8° 20′ south. A little sum in arithmetic will show us that the great nebula is 2° 52′ *north* and twenty minutes *east* of *Rigel*, and this is all we need to know.

Now, employing a low power eye-piece, we point the telescope to *Rigel*. For the first few trials it may be advisable to use a common watch, but this will soon become unnecessary. Having pointed the telescope to *Rigel*, when he is in the center of the field, we read the face of our watch, say ten minutes past eight, and we will allow ourselves one minute to point our telescope to the great nebula. First we move our telescope by the circle nineteen minutes east (for we must *subtract* the minute we shall use in making the pointing when the object is to the *east*) and, by the declination circle we move the telescope 2° 52′ *north* as nearly as possible, and at the end of the minute, or at eleven minutes past eight, the great nebula will be in the center of the field. Refraction may be ignored entirely since our starting point and the object we wish to find are always near each other.

For our next example we will take "HIND's Crimson Star" in *Lepus*, which is in the same neighborhood and we can again use *Rigel* for our starting point. This star is invisible without a telescope, but is readily recognized when found, and therefore is a good object for first trials. WEBB gives its position as R. A. 4^h 54^m and south declination 14° 59′—say fifteen degrees, and refering to our position of *Rigel*, we find the star is fifteen minutes west and 6° 40′ south of *Rigel*. First set on *Rigel*, then, allowing one minute, as before, to point the telescope, observing however that when the object is *west* of our starting point, we must *add* the minute, on account of the westerly motion of the object, we move the telescope *sixteen* minutes west and 6° 40′ south and the telescope is pointed directly to the position the star will occupy at the end of the minute.

It is often desirable to observe a star or planet in the daytime, and we can readily do this by taking the sun as our starting point, but as the sun changes his right ascension about four minutes every day, and the planets, especially *Venus* and *Mercury*, show great changes from day to day, we must have access to a nautical almanac, and we must not only know their positions for that day, but approximately for the hour in which we wish to observe them. These positions are readily found, however, in the almanac, and with the exception of a little more trouble, are quite as good starting-points as our first examples, always working of course from the sun's center.

The method is not yet exhausted however, for, by reversing the order of the first two examples, we can with certainty approximately fix the position of any object whose place we wish to remember. Suppose, for example, we find an object we wish to "lay by for future reference" and desire to fix its position. First, when the object is in the center of the field (a high power eye-piece may be advantageously employed) we read the face of our watch and record the time; then read and *record* the readings of our circles, then point the telescope to some well-known neighboring object and when we have it in the center of the field, again note the time by our watch, and then at our leisure again read the circles. The difference of the two sets of circle readings, plus or minus the interval that elapsed between the two readings of our watch, will give us the position of the object reckoning from the well-known adjacent object to which we last pointed the telescope.

I will illustrate this by an example. Suppose we find an object which we wish to observe at a future time, and that when the object is in the center of the field, we record the time indicated by our watch, say ten o'clock. Then we read the circles and record the readings. Next we point the telescope to some neighboring bright star—(say *Sirius*,) and when he is in the center of the field again read the watch, and let us assume that it is now two minutes past ten, and again read off the difference in the positions of the object and *Sirius*, and let us say the object was twenty degrees north and one hour and ten minutes east. Now, as *Sirius* is in R. A. $6^h\ 40^m$, the object *must* be in R. A. $7^h\ 50^m$ if we take no account of the time interval of two minutes which we occupied in reading the circles, but this must receive attention, and as the object was *east* of *Sirius* and moving *westward*, the two minutes must be subtracted and the corrected position is R. A. $7^h\ 48^m$. As our object was 20° north of *Sirius* and the declination of *Sirius* is 16° 33′ south, we have only to subtract 16° 33′ from 20° and we at once have the declination of the object, which is 3° 27′ north.

I have assumed in the above examples that the telescope was without a driving-clock, but if a clock can be used it is much easier, for while we have the telescope clamped upon the star which we shall take for a starting point, we set the telescope in declination, and then we have only to allow for the time occupied in moving in right ascension, and as this usually takes but a few seconds with small telescopes, we may as a rule, ignore the question of time altogether.

I will add for the benefit of any who may wish to construct a pair of circles as above described, that it is not all necessary to have them adjusted with extreme accuracy as is the case when sidereal time is employed, for we do not work from the *meridian*, but to or from our neighboring known object. The known object should always be in the vicinity of the one whose place is to be ascertained, in order that the small errors in the adjustment of the polar axis, and the eccentricity of the circles may be rendered practically insensible by being nearly the same for both objects.

I. THE SUN'S MOTION IN SPACE.

By W. H. S. Monck, Dublin.

While there is considerable amount of agreement between the various determinations of the sun's motions in space, there is also an amount of discordance which cannot be regarded as satisfactory. It may therefore be desirable to inquire whether this discordance does not arise from the employment of objectionable methods rather than from any errors in the corresponding computations. All the methods which I am aware of start with a classification of the stars whose proper motions are to be considered. Two principles of classification have been adopted by different computers—one depending on the magnitudes of the stars and the other on the amount of their apparent proper motions.

The first method commences by classing together stars of nearly the same magnitude and assuming that the stars comprised in each class are at nearly the same distance from us, while the relative distances of the different classes are computed from the average intensity of the light in accordance with the law of inverse square. To this process there are many objections. First there is strong reason to believe that stars of the same magnitude are situated at widely different distances from us. Indeed if it be true that a Sirian star is on the average nearly two magnitudes brighter than a solar star of the same mass placed at the same distance, these two kinds of stars ought not to be classed together in any inquiry in which their distances are involved. In the next place in order to construct any class numerous enough to be used in our computations we must in our earlier classes include stars which differ very considerably in magnitude. Thus in Mr. Dunkin's computation (*Memoirs of The Royal Astronomical Society*, vol. xxxii) there are only nine stars comprised in his first class and to obtain these he includes *Sirius* and *Spica*, whose difference in magnitude amounts to 2.66 according to the *Harvard Photometry*. The fifty-five stars in his second class include *Antares* 1.06 and δ *Leonis* 2.75; while it is pretty evident that his first class averages more than one magnitude above his second class, thus rendering the assumed multiplier inapplicable. In computing these multipliers according to the law of inverse square, moveover, it is assumed that there is no loss of light in transmission, which is also

open to considerable doubt. It is not surprising that a method which is liable to such grave objections should have yielded unsatisfactory results.

In the second method the stars are classified in accordance with their apparent proper motions, similar assumptions being made as to the distances of the respective classes as in the former instance. But in the first place there seems good reason to believe that different stars are moving through space with very different velocities, while the apparent proper motion depends not only on the distance of the star and its velocity, but also on the degree in which its apparent path is foreshortened owing to the position of the observer. But if the apparent proper motion of the stars is largely influenced by the sun's motion in space a further objection arises. Suppose, for instance, that we are considering the class of stars whose apparent proper motion ranges from 0″.08 to 0″.12 annually and that on the average one-half of this apparent motion is caused by the motion of the sun. The true proper motion of the class will then range from 0″.04 to 0″.24, and some of the stars in the class will be six times as remote (on the average) as others. An inspection of the catalogue of 1167 stars used by Mr. DUNKIN seems to show that this danger is not illusory. Taking the proper motion in parallel I find that of eighty-three stars between 10^h and 12^h R. A., thirty-nine have a proper motion of 0″.10 or upwards annually, while from 16^h to 18^h R. A. only twenty-one out of ninety-eight stars move with this apparent velocity. There seems strong reason to believe that this difference is not due to the greater velocity or greater nearness of the stars between 10^h and 12^h R. A., but to their different positions with regard to the apex of the sun's way. Indeed it does not extend to the proper motions in N. P. D.

Besides the objectionable methods employed, it seems to me that our catalogues of proper motions are by no means free from systematic errors. It is to this cause I think that any considerable preponderance of diminishing or increasing Right Ascensions in an extensive catalogue must be ascribed. If the great majority of the stars returned to their places a little before or a little after the supposed expiration of the sidereal year, the inference would be that the supposed sidereal year was either a little too long or a little too short. In the two catalogues which I examined—that used by Mr. DUNKIN and one of Southern stars (by Mr. STONE) used by Mr. PLUMMER—I find a large preponderance of dimin-

ishing Right Ascensions. To make the diminishing and increasing Right Ascensions balance, we require to reckon not only $0^s.000$ but $-0^s.001$ as increasing Right Ascensions in Mr. DUNKIN'S (or rather Mr. MAIN'S) catalogue, while for Mr. STONE'S catalogue the correction necessary for this purpose amounts to $+0^s.004$. The results produced by these corrections exhibit no slight degree of symmetry, and if such corrections are really requisite, the most elaborate mathematical computations based on the uncorrected motions are not likely to afford very satisfactory results.

The only remaining course—at least until we have a larger supply of spectroscopic proper motions to refer to—is to abandon classification altogether and with it to abandon all suppositions as to the relative distances of the stars. We must then disregard the amount of the proper motion in each case as depending on matters which we cannot ascertain, and attend to the directions only. These directions are, I think, sufficient to determine the position of the sun's apex, provided that the stars examined are sufficiently numerous and varied. I endeavored to apply this method to Mr. DUNKIN'S 1167 stars, but the number did not appear to be sufficient for an exact determination. I therefore divided the Right Ascension into intervals of 1 hour or 15° only, and first tabulated the increasing and diminishing North Polar Distances (reckoning a star which has no motion in N. P. D. as one-half to each).

Limits of R. A.	No. of Stars with increasing N. P. D.	No. of Stars with decreasing N. P. D.	Limits of R. A.	No. of Stars with increasing N. P. D.	No. of Stars with decreasing N. P. D.
h. h.			h. h.		
0 to 1	31	8	12 to 13	23½	13½
1 to 2	43½	10½	13 to 14	28	12
2 to 3	51½	6½	14 to 15	28½	12½
3 to 4	38	6	15 to 16	39½	13½
4 to 5	42	4	16 to 17	22½	21½
5 to 6	48½	11½	17 to 18	26	30
6 to 7	34	6	18 to 19	35	23
7 to 8	30½	9½	19 to 20	33½	38½
8 to 9	33½	11½	20 to 21	33	31
9 to 10	29½	9½	21 to 22	32½	16½
10 to 11	33½	9½	22 to 23	32	22
11 to 12	27½	12½	23 to 24	32	18
Total				810	357

The great preponderance of increasing North Polar Distances in this table clearly indicates that the apex is situated in the Northern Hemisphere, and I may add that its North Declination is considerable, since if it lay near the equator the preponderance of increasing North Polar Distances would not be so great. Next we have to note that there are two regions in which diminishing North Polar Distances ought to be preponderate, viz: between the apex and the North Pole and between the ant-apex and the South Pole. The Southern stars in the catalogue which I am examing are comparatively few, especially at high Southern Declinations, and therefore the table exhibits but faint traces of this second region. The apex clearly lies between the 16th and 21st hours of R. A. and notwithstanding the curious deficiency of diminishing North Polar Distances between the 18th and 19th hours, that interval seems to be the most probable position for the apex. It will be noted too that the region in which diminishing North Polar Distances preponderate is too large to justify us in placing the apex very near the North Pole. A declination of about 45° will, I think, best explain the phenomena on the whole.

I then formed a similar table for the proper motions in Right Ascension adopting the correction already suggested, but this correction has only the effect of converting a relative into an absolute preponderance of increasing Right Ascensions in one part of the sky and hardly affects our conclusions as to the most probable position of the apex.

Limits of R. A.	No. of Stars with increasing R. A.	No. of Stars with decreasing R. A.	Limits of R. A.	No. of Stars with increasing R. A.	No. of Stars with decreasing R. A.
h. *h.*			*h.* *h.*		
0 to 1	24	15	12 to 13	12	25
1 to 2	31	23	13 to 14	11	29
2 to 3	28	30	14 to 15	12	29
3 to 4	28	16	15 to 16	26	27
4 to 5	31	15	16 to 17	18	26
5 to 6	46	14	17 to 18	23	33
6 to 7	24	16	18 to 19	27	31
7 to 8	13	27	19 to 20	41	31
8 to 9	13	33	20 to 21	41	23
9 to 10	11	28	21 to 22	33	16
10 to 11	9	34	22 to 23	38	15
11 to 12	14	26	23 to 24	33	17

Here, if A be the Right Ascension of the apex, there ought to be a preponderance of diminishing Right Ascensions between A and A $-$ 180°, and a preponderance of increasing Right Ascensions between A and A $+$ 180°; while there should be two neutral points corresponding in Right Ascension with the apex and ant-apex respectively. The first of these neutral points is indicated by the change from a preponderance of increasing to one of diminishing Right Ascensions as we pass from the interval 6^h to 7^h to the interval 7^h to 8^h; the second is indicated by an almost equal distribution between 18^h and 19^h. It is true that there is also a pretty equal distribution between 15^h and 16^h, but this evidently lies in the region where diminishing Right Ascensions preponderate and is due to some accidental cause. The interval 18^h to 19^h is thus again marked out for the Right Ascension of the apex. The preponderance of diminishing Right Ascensions between 7^h and 19^h and of increasing Right Ascensions between 19^h and 7^h is moreover large enough to show that the apex cannot be near the North Pole, for in that case the effect in Right Ascensions would be small. With a larger catalogue we could adopt smaller intervals in Right Ascensions and intervals of Declinations also; and with a larger proportion of Southern stars we could determine the position of the ant-apex as well as that of the apex, and use the former as a check upon the latter; and it is one advantage of this method that the process itself shows the degree in which its results may be relied on. My rough estimate of 280° $+$ 45° may be erroneous to the extent of several degrees in both Right Ascensions and Declination, but I think it will be found nearer to the truth than 264° $+$ 25° which Mr. DUNKIN deduced from the same data by applying the method of least squares to the proper motions of the stars as classified by him. The reduction in the sum of the squares of the motions effected by Mr. DUNKIN was moreover very small, whereas the figures given above seem to imply that the apparent proper motions of the stars are largely dependent on the motion of the sun.

But can we by this method ascertain the velocity with which the sun is moving through space? I think we can, as soon as spectroscopic observations have enabled us to estimate the average velocity of the stars. Assuming that the stars are moving indifferently in every direction, one-half of them will be approaching and the other half receding from any point which we may select, and taking the earth as such a point, the spectrocope will

give us the average rate of approach or recession. The North Pole, for instance, is another such point. Half of the stars will be receding from it and the other half approaching it, in consequence of their own laws; but the effect of the sun's motion is to convert the approach into an apparent retrogression in the case of all stars whose velocity of approach is less than that of the sun. Supposing for example that the sun is approaching the North Pole with the average velocity of an approaching star, one-half of the approaching motions will be changed to apparent recessions and the receding stars will outnumber the approaching in the ratio of three to one. According to the catalogue which I have been considering, the increasing North Polar Distances fall somewhat short of this proportion so that the sun's velocity in the direction of the North Pole is a little less than the average of spectroscopic velocities. How much less could, I believe, with sufficient data be determined exactly, and if we know the velocity with which the sun is approaching the North Pole and the exact position of the apex, we can easily compute the velocity in the direction of the apex. My present rough estimate of this velocity is about twenty miles per second, but this may be erroneous by several miles. A catalogue of the proper motions of not less than 10,000 stars would I think be requisite for any computation whose results could be relied on as fixing the position of the apex within two or three degrees, or as determining the sun's velocity without a considerable percentage of possible error. But the method which I have been advocating requires but little mathematical computation and could be applied to 10,000 stars with less labor than the current methods could be applied to 500.

II. THE SUN'S MOTION IN SPACE.

By W. H. S. Monck.

In a paper already communicated to this Society I expressed my opinion that the apparent proper motions of the fixed stars are much more largely dependent on the sun's motion in space than is commonly supposed by astronomers, and that the contrary conclusion was chiefly deduced from erroneous assumptions as to the magnitudes and distances of the stars whose proper motions were under consideration. I have since examined M. Bossert's

list of stars having a proper motion of $0''.5$ or upwards annually in the *Bulletin Astronomique* for March, 1890, and the result has been to confirm my previous conclusions. M. BOSSERT'S list seems to me to contain some duplicates as well as some binary stars, which I think ought to be struck out, but I have in the present paper dealt with his list as I found it. Though the large proper motion of some stars is no doubt due to their vicinity to us, I think it may be fairly assumed that the stars in M. BOSSERT'S list possess more than the ordinary amount of true proper motion, and that consequently if the effect of the sun's motion is plainly evident in the case of these stars we may conclude that the proper motions of other stars are affected by it in a still higher degree. The list contains 269 stars. Of these 10 have no motion in North Polar Distance while of the remainder the motion of 176 is in increasing N. P. D. and only 83 in diminishing N. P. D. Again I remarked that assuming the R. A. of the apex of the sun's way to be 270°, the effect of the sun's motion would be to increase the R. A. for all stars between 270° and 90° R. A. and to diminish it for all stars between 90° and 270°.

M. BOSSERT'S list contains 139 stars whose R. A. lies between 270° and 90°, of which 101 have an increasing R. A., 35 a diminishing R. A. and 3 are neutral; while of 130 stars between 90° and 270°, 33 have an increasing R. A., 96 a diminishing R. A. and 1 is neutral. There is another test which affords equally decisive results. The effect of the sun's motion on that of the stars is insignificant in the case of stars situated near the apex and antapex of the sun's way. Hence, if the apparent proper motions are largely influenced by the sun's motion, stars with large proper motion will exhibit two minima near these points. The average number of stars to each hour of R. A. in M. BOSSERT'S list is a little over 11, but between 6^h and 7^h there are only 5 and between 18^h and 19^h only 3. There are some irregularities in the list but nowhere does the number fall so low as in the two hours which I have indicated. Of 80 stars whose proper motion amounts to $1''$ or upwards not a single one occurs in either of these hours of R. A.

M. BOSSERT'S list also confirms a remark which I previously made as to the necessity of dealing with Sirian and Solar stars separately. On comparing it with the DRAPER *Catalogue* and taking the stars common to both, the Solar stars outnumber the Sirians in the proportion of eight to one. Two explanations

may be offered of this fact. One is that the Solar stars are really moving faster through space than the Sirians; the other is that the Solar stars are about eight times as numerous as the Sirians, but that the Sirian stars, owing to their greater brilliancy, are visible at distances considerably exceeding those at which Solar stars of equal mass can be seen, in consequence of which their number has been over-estimated.

Should the old methods of mathematical computation be still adopted, the data for them should at all events be improved. Besides separating Sirian from Solar stars, magnitudes (when they enter into the computation) should in all cases be determined photometrically. When this has been done, assuming the distribution of the stars to be uniform and no light lost in transmission, the proper motions can be reduced to a common basis by multiplying the observed proper motion of each star by $10^{\frac{m}{5}}$, where m is the magnitude of the star. The unit in this case is a star whose photometric magnitude is 0. If the stars are classified not according to their magnitude but according to their proper motions, a method of successive approximation might be adopted. Thus, suppose that we determine the sun's motion from the class of stars whose proper motions lie between $0''.08$ and $0''.12$ annually. Correct these proper motions by the result thus obtained, rejecting those which are considerably increased or diminished and inserting in place of them stars whose apparent proper motion is above $0''.12$ or below $0''.08$ but which would fall within these limits on correction, and then repeat the computation with the new class of stars. Previous determinations of the solar motions might suffice for a rough correction at the outset. Such a method would no doubt be laborious but great labor has already been bestowed on such computations. Unfortunately the results hitherto attained can hardly be regarded as repaying this labor. If two or three successive approximations gave almost identical results we might consider the problem solved unless the stars employed in the computation had some systematic motion of their own.

DISCOVERY OF NEW RILLS ON THE MOON FROM THE LICK OBSERVATORY NEGATIVES.

By Professor L. WEINEK, Director of the Observatory of Prague.

[Abstract by Professor HOLDEN.]

Professor WEINEK has asked me to communicate to the Society a brief account of new rills which he has discovered in his examination of the negatives of the moon made at Mt. Hamilton. It was hoped to accompany this note with reproductions of Professor WEINEK's exquisite drawings, but it is not possible to do so, at present. The drawings will appear in due time in the Publications of the Observatory of Prague, and also in a volume to be printed by the Lick Observatory by the aid of the generous gift of Mr. LAW. (See *Publications* A. S. P., vol. iii, p. 377.)

Cleomedes (drawn 20-fold enlarged, Nov. 19, 1891, from the Mt. Hamilton negative of August 31, 1890, 14^h 27^m P. s. t.). Between craters B and *i* (NEISON). The westernmost rill originates at the foot of a hill north of c, and can be traced up to an angle in the west wall. There is a short rill crossing the first described. Both these rills show bright edges (walls) and seem, therefore, to be real. Other rills are shown on Professor WEINEK's drawings. These rills should be verified either on other plates (not now available) or at the telescope.

Eimmart (drawn 20-fold enlarged, Nov. 22, 1891; discovered Nov. 21, on the Mt. Hamilton negative of Aug. 23, 1888). Two long rills extending east and west, south of *Eimmart* S (SCHMIDT). These have bright walls and are well seen on the plate taken 1890 Aug. 31, 14^h 25^m and not so well on the plate taken at 14^h 27^m on the same night. They are crossed by many others which are not so certain.

Picard (drawn 20-fold enlarged, from the Mt. Hamilton negative of Aug. 31, 1890, 14^h 25^m P. s. t.).

New rills discovered Dec. 1, 1891.

1. North of *Picard;* fork-shaped, and with bright walls.
2. West of *Picard;* rill with crater formation; probable.
3. Also rills east of *Picard.*

A drawing is required to explain the situation of these objects.

Longomontanus (drawn 20-fold enlarged, from the Mt. Ham-

ilton negatives of Oct. 12, 1891, $7^h\ 29^m\ 7^s–11^s$ P. s. t. and of Oct. 12, 1891, $7^h\ 30^m\ 53^s–56^s$ P. s. t.).

New rills discovered 1892 Jan. 31.

1. Extending right through *Longomontanus* from south to north with a knee in the middle towards the west. Bright walls.

2. In the southern interior portion, crossing No. 1, and extending to the central peak.

3. Rill east of and close to the central peak.

4. Valley to the central peak towards the north, etc.

The foregoing bare catalogue seems to do scant justice to Professor WEINEK'S discoveries as they are exhibited on the beautiful pencil drawings now at the Lick Observatory, but it is unfortunately all that can be given at this time, as these drawings require the most perfect processes of copying (heliogravure) in order to represent the originals. E. S. H.

THE MOON, PHOTOGRAPHED AT THE LICK OBSERVATORY

August 31, 1890, 14 h. 27 min. P. S. T.

NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

The Systems of Bright Streaks on the Moon.

The systems of bright streaks on the moon which radiate from the craters *Tycho*, *Copernicus*, *Kepler*, *Byrgius*, *Anaxagoras*, *Aristarchus* and *Olbers* are visible at the first glance in even the smallest telescope, and have been known since Galileo's time. Similar, though less prominent systems radiate from *Euler*, *Proclus*, *Aristillus*, *Timocharis*, *Menelaus*, *Mayer* and other formations. These streaks have been more or less accurately depicted in the moon-maps of Lohrmann, Beer and Mædler, and Schmidt; and they are beautifully and plainly shown in lunar photographs.

Comparisons of the negatives taken at the Lick Observatory with the best maps have shown me that the latter do not always agree with the former and the question arises whether each such bright streak always occupies one and the same position on the moon, no matter what the moon's age and phase may be. To settle such a question by visual observations would be a very long and arduous task, and I believe it has always been tacitly assumed by selenographers that these bright streaks remain in one and the same situation and that they do *not* shift as the phase changes.

It is clear, however, that the question of whether they do or do not shift slightly as the moon's age varies is an important one. A shift would indicate a phase in the bright streak itself and would throw some light on its nature which is, as yet, not understood.

A careful examination of glass-positives from our negatives would settle this fundamental question, and it appears to be worth making and not very difficult to make. If the bright

streaks were found to vary in position systematically as the illumination changed, this would be a fact of great importance.

If, on the other hand, the streaks could be proved to remain in fixed positions, no matter what the illumination might be, this also would be well worth establishing.

I shall be very glad to assist any observer who has sufficient time to devote to this question by supplying him with the material for examination; and it appears to me that the necessary time would be well spent. I have consulted Professor WEINEK in this regard and he agrees with me that the research (which only needs patience and conscientiousness) is very interesting and well worth undertaking. EDWARD S. HOLDEN.

A BRIGHT METEOR.

PHŒNIX (A. T.), February 3, 1892.—A meteor was seen northeast of here Monday night (February 1). The meteor fell with a roaring noise that was heard here, thirty-five miles distant. —S. F. *Chronicle*.

STEEL ENGRAVING OF THE GREAT TELESCOPE.

The frontispiece of this number of the *Publications* is an impression from a steel engraving of the 36-inch telescope which has been made for Messrs. WARNER & SWASEY, the designers and makers of the mounting. They have kindly presented to the Society 1000 impressions from this plate for distribution to the members. The Committee on Publication begs to acknowledge this courtesy in the name of the Society.

E. S. H., C. E. Y., W. W. C.

THE BRUCE TELESCOPE FOR THE HARVARD COLLEGE OBSERVATORY.

A recent letter from Professor PICKERING refers to the BRUCE telescope, of which so much is expected, and says that Mr. ALVAN CLARK has received the four discs of glass for the objective and that the prism to go in front of the object-glass is entirely completed. It is hoped to have the entire instrument ready for its work in about a year. E. S. H.

Congressional Grant of Additional Land for the Uses of the Lick Observatory.

Hon. E. F. Loud, of the House of Representatives, and Hon. Charles N. Felton, of the Senate, have procured the passage of a bill (H. R. 3933, 52d Congress, 1st Session), granting to the Regents of the University of California the following described public lands, in trust, for the use of the Lick Observatory, *namely*, the N. W. ¼ of Section 3; the E. ½ of Sec. 4; the N. W. ¼ of Sec. 4; the N. W. ¼ of the S. W. ¼ of Sec. 4; all in Township 7 S, Range 3 E, Monte Diablo Base and Meridian, comprising about 680 acres. The 44th Congress had previously granted 1350 acres in 1876 (see *Publications* of the Lick Observatory, vol. I, page 12, map). Mr. Lick during his lifetime had purchased a tract of $191\frac{49}{100}$ acres; Mr. R. F. Morrow had presented a tract of about 40 acres; and the Legislature of California set aside in 1890 the N. ½ of Sec. 16 (320 acres). The total area of the Reservation is therefore about 2581½ acres at the present time. The recent additions insure the Observatory against encroachment for all time.

E. S. H.

Photograph of Mare Crisium and Vicinity.

The plate in this number of the *Publications* is copied from a negative made at the Lick Observatory on August 31, 1890. It represents about the best results which can be obtained by "process-cuts"; and it hardly does justice to the original. In a subsequent number of the *Publications* we shall be able to give a heliogravure reproduction of Professor Weinek's drawing of this region, when the great superiority of the latter process will be evident.

E. S. H.

Large Sun-Spot of February, 1892.

This spot was, I believe, first seen by Mr. W. J. Hussey of the Ann Arbor Observatory on February 5.* It was independently discovered, *with the naked eye*, by Professor Schaeberle at Mt. Hamilton on February 9. Since that time a very large number of photographs has been made of it, at the Lick Observatory, by Messrs. Schaeberle and Campbell, using the 40-foot horizontal photo-heliograph. A few of these negatives are very fine and it is hoped to reproduce some of them in the *Publications*.

* It was photographed at Northfield on February 5.

The spectrum of the spot has been observed by Dr. CREW, who has printed a note on the subject in *Astronomy* and *Astro-Physics* for April, 1892. E. S. H.

THE NEW STAR IN AURIGA, FEBRUARY, 1892.

Professor PICKERING of the Harvard College Observatory has kindly sent us prints from his negatives of 1890, February 6, and of 1891, December 17, which cover the region in *Auriga* where the new star has lately appeared (R. A. 5^h 25^m; Decl. $+30° 21'$). The new star is not on the first plate and it appears on the second. It has therefore been of something like its present brightness since December 17 at least. It was not known to exist, however, until February 1, when a postal-card was sent by Dr. ANDERSON of Edinburgh (its discoverer) to the Astronomer-Royal of Scotland. The discovery was at once verified by him and notified by telegraph to observatories in Europe. The news arrived in the United States on February 2, but the telegram did not reach Mt. Hamilton until February 6. Since that time it has been constantly under observation here. Dr. CREW has printed a preliminary account of its visible spectrum in *Astronomy* and *Astrophysics* for April, 1892. Professor CAMPBELL has observed both its visible and its photographic spectrum on every available opportunity and has fixed the place of about 50 bright lines and bands. We have received from the Harvard College Observatory a splendid enlargement from negatives of its photographic spectrum made in Cambridge. Plates suitable for measurement showing its relation to comparison stars near it have been made at Mt. Hamilton with the great equatorial, and Professor BURNHAM has measured its distance from surrounding stars. Professors SCHAEBERLE and CAMPBELL have made naked eye and opera-glass estimates of its visual brightness on nearly every night since February 6. Professor SCHAEBERLE has also secured a large number of plates with the CROCKER photographic telescope which show the new star and *Polaris*, with varying exposures, and which are eminently suitable for fixing its photographic magnitude. Besides such short exposures (1^s—2^s—4^s—8^s—16^s—32^s—64^s—128^s) the latter observer has made a few long exposures on the same region, when the circumstances were favorable, giving all the stars down to about 13 mag. The star is now (March 10) invisible to the naked eye. The reports we have so far received indicate that the weather has not been very favor-

able in the East and in Europe, and it is therefore a matter for congratulation that our sky at Mt. Hamilton has been unusually clear during the past month, so that almost a continuous record has been secured at this observatory. E. S. H.

A Handy Star-Atlas (Messer's).

I have lately seen a Star-Atlas compiled by Herr Jacob Messer, of St. Petersburg, which is very compendious (the page is about 4½ inches by 8¾ inches and the book is about 1¼ inches thick), and which, I should think, would be found extremely convenient for amateur observers who do not care to burden themselves with the larger works.

It contains all the stars visible to the naked eye (1st to 6th magnitudes, inclusive), from the north pole down to 35° south declination, together with a selection of the most interesting double stars, variables, nebulæ, clusters, etc.

The atlas is published in two editions, one German, the other Russian. There are some 250 pages of introductory matter specially designed for amateur observers. E. S. H.

A Large New Nebula in Auriga.

On receiving the announcement, February 6th, of the discovery of Nova Aurigæ, Professor Holden requested me to use the Crocker telescope for photographic observations on this star. The same day (February 6th) the Willard lens was, therefore, strapped to the 6-inch Clark equatorial and a series of exposures made that evening. Similar observations have been made on every clear night up to the present time.

On a plate which I exposed for 150^{m} on the evening of March 21st, I find a large and apparently new nebula in R. A. $5^{h}\ 9^{m}.5$ Dec. $+34° 10'$. The north preceding part of this nebula is in the form of a comparatively slender ray which seems to have its origin in the star W. B. 5^{h}, No. 151. This ray gradually widens —the northern boundary running in an easterly direction for a quarter of a degree or more; the southern boundary runs in a southeasterly direction, passing just a little to the north of the star W. B. 5^{h}, No. 162 (a naked-eye star), around which it appears to bend and then takes a southerly course extending more than a quarter of a degree beyond this star.

In a southeasterly direction the length of the nebula visible on

the plate is more than half a degree, while its width varies from a few minutes of arc, at the star No. 151, to twenty or more minutes opposite the star No. 162.

A photograph taken February 27th which I exposed for 90^m shows, less conspicuously, the same object. Since the 21st the weather has been unfavorable so that the possibility of seeing the nebula *visually* is still a question to be decided.

J. M. SCHAEBERLE.

LICK OBSERVATORY, March 23, 1892.

P. S.—On the evenings of March 24 and 25 I made exposures of 200^m and 195^m respectively. These plates plainly show that the nebula joins the above mentioned stars W. B. 5^h, Nos. 151 and 162. Prints made so as to show only the brightest parts of the nebula reveal the following structure.

A narrow stream of nebulosity issues from the star No. 151 on the east side; a short distance from this star the stream divides into two parts; one running in a southeasterly direction passing the star No. 162 at a distance of two or three minutes of arc, then suddenly curving in towards the star which it joins in the southeast quadrant. This stream is inclosed by the other branch, which first runs in a more easterly direction until it reaches a point northeast of the star No. 162 where it suddenly curves in towards this star and joins it in nearly the same position-angle as the first branch. From this same point of junction a third stream runs from the star in a southerly direction for a distance of 5′ or more and then turns towards the east. On the original plates several very faint nearly equidistant bands of luminosity are shown in the northern part of the nebula. Taken as a whole a certain resemblance to the Orion nebula is apparent.

J. M. S.

ERRATUM IN VOLUME III.

Professor WEINEK points out the following Erratum in Volume III, page 340, line + 12; *for* 2.5^{mm} *read* 0.25^{mm}.

CORRECTION TO PUBLICATIONS NO. 16.

In *Publications* A. S. P. Volume III, page 253, line + 14, *for* "on" *read* "of".

Minutes of the Meeting of the Directors A. S. P., held in the Rooms of the Society, March 26, 1892, from 7.30 to 8 p. m.

A quorum was present.

The minutes of the last meeting were read and approved.

Mr. Richard H. Allen, of Chatham, New Jersey, was elected a life-member. The following members were elected. An asterisk (*) is added to the name of life-members. The membership of the Society is now 432, of whom 51 are life-members.

List of Members Elected March 26, 1892.

T. R. Bannerman	2407 Howard Street, S. F., Cal.
J. T. Brownell	Nyack, New York.
Andrew Carnegie*	5 West 51st St., New York City.
O. E. Cartwright	165 Elmwood Ave., Detroit, Mich.
Mrs. Emelie M. Chabot	Cor. 11th and Madison Streets, Oakland, Cal.
Miss Josie Chabot	Cor. 11th and Madison Street, Oakland, Cal.
The Cosmos Club	Washington, D. C.
Dr. J. H. De Meritt	1335 Vermont Ave., Washington, D. C.
Mrs. Herbert Du Puy	190 Western Avenue, Allegheny, Penn.
J. J. Evans	406 California Street, S. F., Cal.
H. C. Frick*	42 5th Avenue, Pittsburg, Penn.
Dr. C. G. Fuller	39 Central Music Hall, Chicago, Ill.
Hon. Henry E. Highton	528 California Street, S. F., Cal.
Samuel V. Hoffman*	Johns Hopkins University, Baltimore, Md.
Prof. C. N. Jones	N. W. Insurance Co., Milwaukee, Wis.
Christie C. Kanaga	Box 158, Ogden, Utah.
Rev. Edmund Ledger, M.A., F.R.A.S.	Claydon, Ipswich, England.
J. B. Lewis, C. E.	126 Sparks St., Ottawa, Canada.
Chas. Loughridge	Chamber of Commerce Building, Chicago, Ill.
Charles A. Loxton	Walsall, Staffordshire, England.
S. S. McClure	Tribune Building, New York City.
David Mahany	13 East 55th St., New York City.
Edward Thomas Purser	Healdsburg, Cal.
Allan D. Risteen	701 Asylum Avenue, Hartford, Conn.
G. P. Rixford	1713 Pierce Street, S. F., Cal.
T. A. Robinson	320 Post Street, S. F., Cal.
Henry T. Scott	Box 2128, S. F., Cal.
Chas. S. Smith*	25 West 47th St., New York City.

Dr. HENRY STARR	Liberty and Barnett Streets, Baltimore, Md.
Miss ABBY TAFT	Box 45, College Park, Cal.
President ANDREW D. WHITE *	Ithaca, N. Y.
Mrs. RICHARD WOOD	243 Ridge Ave., Allegheny, Penn.

The following resolutions were adopted:

Resolved, That this Board has learned with regret that the business engagements of Mr. CHAS. BURCKHALTER prevent him from further continuing to fill the office of Secretary of the Society, the duties of which he has performed with the greatest fidelity during the last three years.

Resolved, That the thanks of this Society and its Board of Directors are due to Messrs. WARNER & SWASEY for their generous donation of 1000 superb steel engravings of the Lick telescope to be used in our next publication.

Resolved, That this Society and its Board of Directors gratefully recognize the exquisite gift to it by Mr. E. J. MOLERA of a framed alto-relievo in metal of the bust of JAMES LICK, the founder of the Lick Observatory. After attending to other business the Directors adjourned.

MINUTES OF THE MEETING OF THE DIRECTORS A. S. P., HELD IN THE ROOMS OF THE SOCIETY, MARCH 26, 1892, FROM 9 TO 9.45 P. M.

The new Board of Directors was called to order by Mr. MOLERA, A quorum was present. The minutes of the last meeting were approved. The business in hand being the election of officers for the ensuing year, the following officers were duly elected:

President: Mr. J. M. SCHAEBERLE.

Vice-Presidents: Messrs. MOLERA, SOULÉ and VON GELDERN.

Secretaries: Messrs. CAMPBELL and ZIEL.

Treasurer: Mr. ZIEL.

The President was authorized to appoint the various Standing Committees of the Directors and accordingly made the following selections:

Finance Committee: Messrs. PIERSON, MARTIN, ZIEL.

Library Committee: Messrs. MOLERA, VON GELDERN, HILL.

The Standing Committees of the Society are:

Committee on Publication: Messrs. HOLDEN, CAMPBELL and YALE.

Committee on the Comet-Medal: Messrs. HOLDEN *(ex-officio)*, SCHAEBERLE and BURCKHALTER.

The following resolution was adopted:

Resolved: That the Directors of the Astronomical Society of the Pacific extend to Mr. PIERSON their thanks for his valuable services as President of the Society.

It was also—

Resolved: That WM. M. PIERSON be and is hereby elected an Honorary Member of this Society. Mr. PIERSON returned his grateful thanks for the honor conferred upon him, but, for reasons satisfactory, begged to resign his honorary membership, and his resignation was accordingly accepted.

It was, on motion—

Resolved: That the President be empowered to appoint a Com mittee for the purpose of raising the necessary funds for the purchase of a telescope and the building of an observatory in San Francisco.*

Adjourned.

ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE-HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, MARCH 26, 1892.

The meeting was called to order by President PIERSON. The minutes of the last meeting were approved. The Secretary read a list of presents received since the last meeting and the thanks of the Society were voted to the givers. It was *voted* that the thanks of the Society be returned to the California Academy of Sciences for the use of their lecture-hall. A list of thirty-two new members duly elected at the Directors meeting was read to the meeting.

The following papers were presented:

1. Annual Address by the retiring President, Hon. WM. M. PIERSON, San Francisco.
2. The Sun's Motion in Space, by W. H. S. MONCK, Dublin.
3. How to find Celestial Objects with an Equatorial Telescope without the Aid of a Sidereal Time-piece, by CHAS. BURCKHALTER, Oakland.
4. Astronomical Observations in 1891, by TORVALD KÖHL, Odder, Denmark.
5. The Harvard College Observatory Astronomical Expedition to Peru, by Mrs. M. FLEMING, of Cambridge.
6. Discovery of New Rills on the Moon on Lick Observatory Negatives, by Prof. L. WEINEK, of Prague.

The Committee on Nominations reported a list of names proposed for election, as follows:

For Directors: Messrs. ALVORD, CAMPBELL, HILL, HOLDEN, CAMILO MARTIN, MOLERA, PIERSON, SCHAEBERLE, SOULÉ, VON GELDERN, ZIEL.

For Committee on Publication: Messrs. HOLDEN, CAMPBELL, YALE.

Messrs. J. COSTA and L. H. PIERSON were appointed as tellers. The polls were open from 8.15 to 9 P. M., and the persons above named were duly elected.

* The following have been appointed: Messrs. PIERSON, MOLERA, ALVORD and Miss O'HALLORAN.

Report of the Committee on the Comet-Medal:

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED MARCH 26, 1892.

The Comets of 1891 have been

Comet *a;* (unexpected comet) discovered March 29, 1891;
b; (WOLF'S periodic comet) re-discovered May 3, 1891;
c; (ENCKE'S periodic comet) re-discovered August 1, 1891;
d; (periodic comet of TEMPEL, 1869, III; of SWIFT, 1880, IV) re-discovered September 27, 1891;
e; (unexpected comet) discovered October 3, 1891.

It is a noteworthy fact that all the comets of 1891 were first seen by Professor E. E. BARNARD at the Lick Observatory. Of the five comets of the year, Comets *a* and *e* were unexpected and medals have been awarded to Professor BARNARD for their discovery in accordance with the regulations.

Rules adopted by the Comet-Medal Committee for its own guidance.

In addition to the Regulations for the bestowal of the Comet-Medal of the Astronomical Society of the Pacific (printed in these *Publications*, vol. III, pages 145, 146) the Committee has adopted the following rules for its own guidance.

I. All dates referring to comet discoveries, etc., shall be expressed in Greenwich mean time.

II. The annual report of the Committee to the Society shall refer to and include the official actions of the Committee for the last *calendar* year only.

Respectfully submitted,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER, } *Committee on the Comet-Medal.*

The Report was adopted and ordered filed.

POSTSCRIPT: The above report was submitted to the Society as printed. It is, however, erroneous in one important particular and the Committee takes the first opportunity to correct it and to apologize for the mistake. Comet *b* was observed by Dr. R. SPITALER at Vienna on May 1; but, owing to cloudy weather, the observation was not verified by him till June 1. In the meantime Professor BARNARD independently discovered the comet on May 3. Dr. SPITALER'S observation was printed in the *Astronomische Nachrichten*, no. 3042, which only reached California at the end of June, and was then overlooked. The re-discovery of Comet *b* should therefore have been also credited to Dr. SPITALER in the foregoing report, and the Committee regrets that this was not done at the proper time. In order to make the history of the Comets of 1891 more complete it might be added that Mr. W. F. DENNING, of Bristol, independently found Comet *a* one day after it had been discovered by Professor BARNARD, and Comet *d* three days subsequently to the discovery.

The Treasurer read his annual report as follows:

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 26TH, 1892.

GENERAL FUND.

Receipts.

Cash Balance March 28th, 1891		$ 744 65
Received from dues	$3,320 86	
" " sale of publications	55 19	
" " Montgomery Library Fund	9 84	
" " Life Membership Fund (interest)	11 12	
	$3,397 01	
Less transfer to Life Membership Fund	699 83	2,697 18
		$3,441 83

Expenditures.

For publications	$1,280 72	
" general expenses	1,209 91	$2,490 63
Cash balance March 26th, 1892		951 20
		$3,441 83

LIFE MEMBERSHIP FUND.

Received from General Fund	$699 83	
" " interest	11 12	
	$710 95	
Less interest transferred to General Fund	11 12	
Cash balance March 26th, 1892		$699 83

DONOHOE COMET-MEDAL FUND.

Cash balance March 28th, 1891	$527 35	
Interest	28 84	
Cash balance March 26th, 1892		$556 19

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash balance March 28th, 1891		$1,590 11	
Interest		85 14	
		$1,675 25	
Expended for books and binding	$31 60		
Payment to General Fund	9 84	41 44	
Cash balance March 26th, 1892			$1.633 81

FUNDS.

General Fund. Balance on deposit with Grangers Bank		$ 951 20
Life Membership Fund. Balance on deposit with San Francisco Savings Union		699 83
Donohoe Comet-Medal Fund. Balance on deposit with San Francisco Savings Union		556 19
Alexander Montgomery Library Fund. Balance on deposit with San Francisco Savings Union	$838 60	
Alexander Montgomery Library Fund. Balance on deposit with German Savings and Loan Society	795 21	1,633 81
		$3.841 03

F. R. ZIEL, *Treasurer.*

SAN FRANCISCO, March 26th, 1892.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was accepted and adopted and the Committee discharged.

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN—Your Committee appointed to audit the accounts of the Treasurer, have made an examination of said accounts from the commencement of his term to the present date and find them correct.

(Signed) M. M. O'SHAUGHNESSY,
OTTO VON GELDERN,
FREDK W. ZEILE.

SAN FRANCISCO, March 26th, 1892.

The President then read his annual address. On motion the thanks of the Society were returned to Secretary CHARLES BURCKHALTER for the able and conscientious manner in which he has performed the duties of Secretary of the Society for the last three years. The thanks of the Society were voted to the retiring Officers and Directors.

The meeting then adjourned.

OFFICERS OF THE SOCIETY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society. at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

LUNAR ECLIPSE OF JANUARY 28, 1888.
DRAWN BY PROFESSOR L. WEINEK.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. [illegible] San Francisco, California, [illegible] November [illegible]

THE TOTAL ECLIPSE OF THE [illegible] JANUARY [illegible]

By Professor L. We[illegible]

The [illegible] is preserved by the [illegible] atmosphere of the earth [illegible] placed by anyone. [illegible] against the dark sky, [illegible] tints of red, brown and [illegible] beautiful sight, and seeks to [illegible] impressions I was led to [illegible] morning of the 28th of January, 1888 [illegible] I made notes during the eclipse [illegible] where they were to be seen, and [illegible] painted the picture in water colors. [illegible] memory, the following would seem the [illegible] a correct picture of the appearance and [illegible] light. The night scene should first be painted [illegible] the aid of lamp light. In this case, however, [illegible] exact [illegible] made by daylight, could not be relied upon [illegible] light changes the appearance of the colors considerably [illegible] correct [illegible] have to be found by experiment. [illegible] having been produced by lamp light, would [illegible] an entirely wrong impression of the true [illegible] of the original. Consequently it would be [illegible] necessary to [illegible] the picture by [illegible] with the same [illegible] light [illegible] examining it [illegible]

[illegible] the Society by L. K[illegible]

LUNAR ECLIPSE OF JANUARY 28 1888

DRAWN BY PROFESSOR [illegible]

PUBLICATIONS

OF THE

omical Society of the Pacific.

SAN FRANCISCO, CALIFORNIA, MAY 31, 1892. No. 23.

TOTAL ECLIPSE OF THE MOON OF JANUARY 28, 1888.

BY PROFESSOR L. WEINEK OF PRAGUE.*

The wonderful coloring of the moon, when more than one-half of its disc is immersed in the shadow of the earth, which, as we know, is produced by the refraction of the rays of the sun in the atmosphere of the earth itself has as yet not been faithfully reproduced by any one. While the eclipsed moon stands out glowing against the dark sky, it offers such a variety of the most delicate tints of red, brown and blue that the artist is inspired by the beautiful sight, and seeks to reproduce what he sees. Through similar impressions I was led to attempt the painting of the phenomenon of the 28th of January, 1888. Relying upon my color-memory I made notes during the eclipse of the colors and localities where they were to be seen, and the very next morning I executed the picture in water colors. Without relying upon one's memory, the following would seem the safest method by which to make a correct picture of the appearance and values of colors seen at night. The night scene should first be painted at the telescope by the aid of lamp light. In this case, however, the color gradations, made by daylight, could not be relied upon, as artificial light changes the appearance of the colors considerably; the correct tints would have to be found by experiment. Moreover, this picture, having been produced by lamp light, would, if examined by day, give an entirely wrong impression of the true appearance of the original. Consequently it would become necessary to illuminate the picture by day with the same lamp, after excluding all other light (perhaps by placing the picture in a closed box and examining it through a suitable opening) and to

* Translated for the Society by F. R. ZIEL, esq.

look upon it as a new original, and then to copy it by daylight in the usual manner.

As regards my observations of this eclipse I refer to my article on the subject published in No. 2846 of the "*Astronomische Nachrichten.*" I observed with the six-inch STEINHEIL Refractor of the Prague Observatory, with a power of sixty diameters, and made my picture at $11^h\ 18^m$ Prague mean time. At this hour the rim of the umbra of the earth's shadow passed through the centre of *Mare Nectaris*, through *Mare Tranquillitatis* and east of *Mare Crisium* as far as *Mare Humboldtianum*. Towards the bright portion of the moon the grayish black shading of the umbra assumed a smoky brown hue, in consequence of the penumbra of the earth; whereas towards the eclipsed portion, south of *Tycho* and north of *Lacus Mortis* it changed to a bright blue tint, and still farther towards the northeast it turned to a most beautiful red, which may be described as being a subdued mixture of *rouge de saturne* and *carmine;* it exhibited almost all the detail of the lunar landscape, together with numerous bright objects. This red coloring was particularly beautiful over *Mare Imbrium*, *Plato*, *Sinus Iridum*, *Copernicus*, *Kepler* and *Aristarchus*, and extended in an easterly direction beyond *Gassendi;* while westerly from this crater *Mare Nubium* and *Mare Humorum* assumed a sombre black-brown aspect. The crater *Aristarchus* was as conspicuous among all other objects during the eclipse as it is when the moon is fully illuminated, owing to its remarkable brightness. In consequence of the technical difficulties which are encountered in the process of printing in colors, the relative values of the colors as well as the gradual decrease of the line of the shadow of the earth are not presented in the accompanying picture as correctly as might have been desired. On the whole, however, this reproduction may be called a satisfactory one.

PRAGUE, November 10th, 1891.

DISCOVERY OF A NEW CRATER ON THE MOON.

BY PROFESSOR WEINEK AT PRAGUE.

[Abstract by Professor HOLDEN.]

In the *Naturwissenschaftliche Wochenschrift* of February 14, 1892, Professor WEINEK gives an account of a new crater discov-

ered by him on the moon with the 6-inch telescope of the Observatory of Prague, on April 1, 1890. Its situation is

East Longitude —49°.2
South Latitude —12°.6

Its interior diameter is about 1800 meters or 1 nautical mile (1″).

This object has been verified by T. GWYN ELGER, esq. (see the *Observatory*, February, 1892, p. 113), and its position and surroundings sketched by Professor HOLDEN with the 12-inch telescope at Mt. Hamilton. It is somewhat remarkable that SCHMIDT'S great lunar map does not show this formation.

SIRIUS.

BY ANDREW GRIEG, TAYPORT, SCOTLAND.

This is the most brilliant star in the heavens, and is sometimes called the leader of the host of heaven. It lies under the beautiful constellation of *Orion*, and a little to the left-hand. Its splendor is so great that it has been perceived at mid-day with a telescope of half-inch aperture, and it has even been seen with the naked eye in broad sunshine. It is one of the stars whose parallax is known, and consequently its distance. The recent determination of its parallax by Dr. GILL, Royal Astronomer at Cape of Good Hope, shows *Sirius* to be much nearer than it was formerly believed to be. Its distance is equal to about nine light-years. Dr. HUGGINS, the eminent Spectroscopist and President of the British Association, tells us that the nearest star is so far off, that if it were approaching us at the rate of one hundred miles per second, a whole century of such rapid approach would not do more than increase its brightness by the one-fortieth part. Photometric observations combined with its ascertained parallax show that *Sirius* emits from forty to sixty times the light of our sun.

The old astronomical methods cannot tell us if the stars are coming directly towards us, or going directly from us. The spectroscope here comes to our aid, and enables us to find the motion of a star in the light of sight. It can measure the speed of approach or of recession of a heavenly body with very great accuracy—probably to about a mile per second. The early spec-

troscopic observations at Greenwich seem to show that *Sirius* recedes from us at one time with a velocity of about twenty-two miles per second, and at another time is coming towards us at the same rate, as it moves in an elliptic orbit.

Certain minute changes in the motions of this brightest of the stars induced BESSEL, the famous astronomer of Königsberg, to suspect the existence of some, as yet unseen, companion sun, whose disturbing influence might account for the unusual displacements. AUWERS, another astronomer, calculated the probable elements of this unseen disturbing mass. Ultimately, a companion star was discovered by Mr. ALVAN G. CLARK (maker of the object-glass for the great LICK telescope), by means of the refractor of 18½-inch aperture made by himself. This excellent instrument now belongs to the Observatory of Northwestern University. The companion, though at least one-tenth as heavy as *Sirius* itself, can only be seen under favorable conditions, for its light is not more than one-12,000th part of that emitted by *Sirius*.

THE PROPER MOTIONS OF STARS WITH DIFFERENT SPECTRA.

By W. H. S. MONCK.

Having recently examined M. BOSSERT's catalogue of stars with proper motion of 0″.5 annually, with the spectra of such as I could identify in the DRAPER catalogue, I think the result worth giving, especially as the spectra of the remainder can be tabulated according as they are examined. M. BOSSERT's catalogue sometimes includes two members of a binary system and in other places two determinations of the proper motion of the same star (occasionally disguised by giving it a different designation). Duplicates of this kind can be detected when the stars are arranged in order of R. A. instead of by the magnitude of their proper motions, and this order will, I think, also bring to light the fact that the motion of the sun in space affects the apparent proper motions of the stars more largely than is commonly supposed. Assuming the R. A. of the sun's *goal* to be 280°, its motion will tend to diminish the Right Ascensions of all stars between 100° (6^h 40^m) and 280° (18^h 40^m) and to increase the Right Ascension of all

stars between 280° and 100°. It will also tend to increase the N. P. D. of all stars save those situated between the *goal* and the North Pole on the one hand and those between the *quit* and the South Pole on the other. Very evident traces of this will be found in the following table. The places are those for 1890. The proper motion in R. A. is in seconds of time.

No.	Name.	Spectrum.
1.	β Cassiopeia	F
2.	248 Lal	—
3.	ζ Toucan	—
4.	475 Lal	—
5.	β Hydra	—
6.	147 Lac	F
7.	999 Lal	E
8.	54 Pisces	H
9.	172 Lac	—
10.	1045 Lal	—
11.	1065 Lal	H
12.	1198 Lal	—
13.	η Cassiopeia	F
14.	189 Piazzi 0^h	H?
15.	μ Cassiopeia	H
16.	1964 Lal	—*
17.	1966 Lal	—
18.	ν Phœnix	—
19.	2387 Lal	—
20.	2450 Lal	H
21.	2635 Lal	—
22.	2682 Lal	—
23.	2966 Lal	—
24.	3022 Lal	—
25.	υ Andromeda	F
26.	107 Pisces	F
27.	τ Cetus	G?
28.	159 Piazzi 1^h	—†
29.	χ Eridanus	—
30.	3277 Bradley	—
31.	δ Triangulum	F
32.	4141 Lal	—
33.	4268 Lal	E‡
34.	123 Piazzi 2^h	H
35.	4855 Lal	H
36.	5490 Lal	—
37.	ι Perseus	F
38.	12 Eridanus	F
39.	113 Weisse	—
40.	6108 Lal	—
41.	1060 Lac	—
42.	ζ^1 Reticulum	—
43.	ζ^2 Reticulum	—
44.	6320 Lal	—
45.	6429 Lal	—
46.	ε Eridanus	K
47.	10 Taurus	F
48.	6788 Lal	—
49.	6772 Lal	H
50.	δ Eridanus	I
51.	6888 Lal	—
52.	τ^6 Eridanus	F
53.	735 Groomb	—
54.	7443 Lal	—
55.	7653 Lal	F
56.	o^2 Eridanus	H?

* The DRAPER *Catalogue* gives a star at 1° 4′ + 22° 23′ with a doubtful spectrum A.

† Two stars near this point, one with spectrum A and the other G? Neither probably identical.

‡ Identification doubtful. LALANDE makes the star fainter than in the D. C.; same remark of No. 35, and some others, but LALANDE's magnitudes are usually less than the photometric.

No.	Name.	Spectrum.
57.	8375 Lal	—
58.	9011 Lal	—*
59.	9012 Lal	A
60.	π^1 Orion	F ? †
61.	1189 Weisse	—
62.	m Taurus	E
63.	λ Auriga	F
64.	9960 Lal	—
65.	9986 Lal	H?
66.	61 Piazzi 5^h	—‡
67.	10299 Lal	—§
68.	990 Groomb	—
69.	146 Piazzi 5^h	I
70.	10797 Lal	—
71.	2138 Lac	—
72.	δ Lepus	I
73.	11196 Lal	—
74.	2106 Lac	—
75.	1159 Groomb	F
76.	Sirius	A?
77.	2501 Lac	—
78.	13427 Lal	—
79.	305 Piazzi 6^h	E?
80.	13849 Lal	E?
81.	14146 Lal	—
82.	2740 Lac	—
83.	Procyon	F
84.	Pollux	K?
85.	1339 Groomb	I
86.	2957 Lac	—
87.	15290 Lal	—
88.	15547 Lal	—
89.	15565 Lal	—
90.	15950 Lal	E
91.	321 Piazzi 8^h	—‖
92.	181 Weisse$_2$	—
93.	16304 Lal	E
94.	3386 Lac	—
95.	17161 Lal	—
96.	1384 Fedorenko	—
97.	ρ^2 Cancer	H
98.	ι Ursa Major	A
99.	10 Ursa Major	F
100.	18067 Lal	—
101.	81 Cancer	H
102.	18115 Lal	H
103.	θ Ursa Major	F
104.	11 Leo Minor	H
105.	19022 Lal	—
106.	20 Leo Minor	A?
107.	1643 Fedorenko	H
108.	γ Leo	K
109.	1646 Groomb	A?
110.	1688 Fedorenko	—¶
111.	520 Weisse	—**
112.	α Crater	I?
113.	21185 Lal	—
114.	21258 Lal	—
115.	469 Mayer	E
116.	ξ Ursa Major	G
117.	32 Piazzi 11^h	—††
118.	11677 A. O.	—

* A star near this point with spectrum H.

† This seems to be the star designated π^1 *Orion* in the *Harvard Photometry*. I have given its spectrum accordingly.

‡ The position is very near 23 *Orion* (spectrum A) but the magnitudes differ considerably.

Perhaps identical with D. C. No. 3089, spectrum H.

‖ This seems to be the same star as the foregoing. One determination is from the Seven Year Catalogue and the other from Paris Observations.

¶ Apparently the same star as the foregoing. One determination is from the A. N. and the other by ARGELANDER.

** This star does not seem to be identical with D. C. No. 5436, spectrum F.

†† Probably not identical with D. C. No. 5689, Spectrum H ?

No.	Name.	Spectrum.
119.	83 Leo	I
120.	20 Crater	—
121.	22069 Lal	F
122.	1822 Groomb	—
123.	4887 Lac	—
124.	β Leo	A
125.	β Virgo	G
126.	1830 Groomb	A?
127.	4955 Lac	—
128.	22585 Lal	—*
129.	22632 Lal	A†
130.	22701 Lal	—
131.	69 Weisse	—
132.	22908 Lal	—
133.	22954 Lal	E
134.	22986 Lal	—
135.	8 Can. Ven.	F
136.	γ Virgo	F
137.	33 Virgo	H
138.	23806 Lal	—
139.	23917 Lal	—
140.	23995 Lal	—
141.	δ Virgo	M‡
142.	24168 Lal	—§
143.	24414 Lal	H
144.	42 Coma	F
145.	43 Coma	F
146.	24504 Lal	—
147.	61 Virgo	H
148.	241 Weisse_2	A
149.	216 Weisse	—
150.	24774 Lal	—
151.	70 Virgo	F
152.	25012 Lal	—
153.	ι Centaurus	—
154.	25372 Lal	—
155.	25404 Lal	—
156.	τ Boötes	F
157.	25484 Lal	—
158.	θ Centaurus	—
159.	Arcturus	K
160.	26289 Lal	H?
161.	26630 Lal	E
162.	127 Piazzi 14^h	—‖
163.	α_1 Centaurus	—
164.	α_2 Centaurus	—¶
165.	728 Weisse	—
166.	27026 Lal	—
167.	212 Piazzi 14^h	—
168.	27298 Lal	—
169.	27274 Lal	—
170.	D M 2874 + 25	—
171.	14318 A. O.	—
172.	14320 A. O.	—**
173.	27744 Lal	—††
174.	5 Serpens	F
175.	268 Weisse	—
176.	28607 Lal	—
177.	β Tr. Aus.	—
178.	39 Serpens	—
179.	χ Hercules	F
180.	γ Serpens	F
181.	49 Libra	—
182.	ρ Corona Bor.	F

* Does not seem to be identical with either D. C. No. 5972 or No. 5992.

† Identification (with 67 Ursa Major) doubtful.

‡ This is the only star in the list with a spectrum of the third type. Its proper motion is only 0″.50 annually.

§ This is the only case in which a star occurs twice in M. Bossert's list under the same name.

‖ Seems to be identical with the foregoing star. The former determination is by Argelander and the latter from A. N.

¶ Binary companion of the foregoing. Proper motions no doubt really agree.

** Perhaps a distant binary companion of the foregoing.

†† Perhaps identical with D. C. No. 6939, spectrum H.

No.	Name.	Spectrum.
183.	29437 Lal	—
184.	18 Scorpion	F?
185.	30024 Lal	—
186.	30044 Lal	—
187.	ξ Hercules	G
188.	ε Scorpion	—
189.	30694 Lal	—
190.	31055 Lal	—
191.	31132 Lal	—
192.	36 Ophiuchus	I
193.	9383 Stone	—*
194.	30 Scorpion	—
195.	72 Hercules	E
196.	322 Weisse	—
197.	32047 Lal	H †
198.	514 Weisse	—
199.	26 Draco	F
200.	17415 A. O.	—
201.	μ Hercules	I?
202.	1005 Weisse	—
203.	70 Ophiuchus	K
204.	η Serpens	K
205.	χ Draco	F
206.	34986 Lal	—
207.	36245 Lal	H
208.	b Aquila	H
209.	2459 Bradley	H
210.	8139 Lac	—
211.	36872 Lal	— ‡
212.	3205 Fedorenko	H
213.	σ Draco	I?
214.	Altair	A
215.	8262 Lac	—
216.	38100 Lal	—
217.	38139 Lal	—
218.	δ Pavo	—
219.	38380 Lal	H
220.	38383 Lal	—
221.	8362 Lac	—
222.	8381 Lac	—
223.	38692 Lal	—§
224.	3436 Fedorenko	E?
225.	20452 A. O.	—
226.	802 Weisse	—
227.	39816 Lal	—
228.	39866 Lal	—
229.	40215 Lal	—
230.	η Cepheus	K
231.	8620 Lac	—
232.	3638 Fedorenko	A
233.	1454 Weisse	—
234.	40849 Lal	—
235.	61^1 Cygnus	H
236.	61^2 Cygnus	—‖
237.	97 Weisse	—
238.	3738 Fedorenko	—
239.	τ Cygnus	F
240.	41363 Lal	—
241.	21319 A. O.	—
242.	γ Pavo	—
243.	8960 Lac	—
244.	42883 Lal	—
245.	ε Ind	—
246.	43205 Lal	—
247.	9061 Lac	—
248.	43492 Lal	A?
249.	ν Ind	—
250.	ξ Pegasus	F

* Same as foregoing with identical determinations by AUWERS and STONE.

† Identification doubtful. D. C. gives same place for 1900 as BOSSERT for 1890.

‡ Same as foregoing star.

§ Probably same as foregoing but the determinations are discordant. The first is from the A. N. and the second by ARGELANDER.

‖ Probably a binary companion of the foregoing star with identical proper motion. The spectrum is that of the pair.

No.	Name.	Spectrum.	No.	Name.	Spectrum.
251.	σ Pegasus	F	259.	9537 Lac	—
252.	44964 Lal	—	260.	ι Pisces	F
253.	9352 Lac	—	261.	46495 Lal	H
254.	4371 Fedorenko	—	262.	9585 Lac	—
255.	3077 Bradley	H	263.	46650 Lal	—
256.	45455 Lal	—	264.	23166 A. O.	—
257.	γ Pisces	I	265.	85 Pegasus	E
258.	45599 Lal	—	266.	32416 Cordoba	—

It is perhaps too soon to draw results from a table so incomplete as the foregoing. It, however, suggests the following conclusions: First, the sun is one of a cluster of stars distinguished from the others by their vicinity and large proper motion and also by the great preponderance of stars whose spectra are of the second or solar type. This cluster also includes a very large proportion of binary stars whose orbits are capable of computation. Second, while the motions of the stars in this cluster afford very strong evidence of the sun's motion in space, the effect in R. A. is greater and the effect in N. P. D. less than when we examined the proper motions of stars not belonging to the cluster; whence it would seem that the cluster has a northerly drift in space, thus making the direction of the sun's *goal* apparently less northerly than its true position. The cluster probably contains many more stars than those comprised in the foregoing list; for besides faint stars with large proper motion which have hitherto escaped detection it must be recollected that in certain parts of the sky a very small motion opposed to that arising from the sun's motion may be equivalent to a very large one in the opposite direction. In the one case we are dealing with the difference of two motions; in the other, with the sum. The table indicates this plainly. Only five stars occur between 6^h and 7^h, the R. A. of the sun's *quit*, and only three between 18^h and 19^h, the R. A. of his *goal*, and in none of these cases save *Sirius* does the proper motion amount to $1''$ annually. The sun's motion is very probably a combination of the drift of the cluster with an orbital motion round some point in the cluster.

(For readers who have not seen the DRAPER catalogue I may mention that the letters A to D inclusive represent varieties of the first type of spectrum, E to L inclusive varieties of the second type and M the third type.)

P. S.

16 Earlsfort Terrace, Dublin,
March 14, 1892.

Dear Sir: Since sending you my last paper on the proper motions of the stars I arrived at some results which I think may interest you and may lead to further inquiries at the Lick Observatory and elsewhere.

The second or solar class of stars are divided in the Draper catalogue and elsewhere into several subdivisions. There are two of these which I would propose to distinguish as Capellan and Arcturian from the principal stars belonging to them. The Capellan include E and F of the Draper catalogue, the Arcturian H, I, K and L, with perhaps G, but I am not sure of its position. My conclusion is that the Capellan is the prevalent type among the *nearer* stars and that it is so in a very marked degree.

Taking Mr. Gore's list of double stars with computed orbits (the computability of an orbit I take to be strong evidence of comparative nearness), there are about 20 Capellan stars out of some 43 or 44 which are also found in the Draper catalogue. They outnumber the *Sirians* which are a much more numerous class and are about three times as numerous as are the Arcturians which are at least as numerous over the whole sky, I think much more so. I made a further comparison with Mr. Main's catalogue of stars with large proper motion which I take to be further evidence of vicinity. Taking 0″.1 per annum as the limit and comparing Main's catalogue with the Draper catalogue I found that 24 per cent. of the *Sirian* stars were over this limit, 36 per cent of the Arcturian (and about the same proportion for stars of the third type which I may perhaps call Antarian), and 65 per cent. of the Capellan. As the stars became fainter the difference appeared to become more strongly marked. It almost seems as if the sun was one of a cluster of Capellans with only a stray intruder of any other spectrum. I disregarded the (?) in the Draper catalogue when classing the stars. In the paper which I sent I believe it would appear that there is a great preponderance of Capellan stars if we allow for their comparative paucity over the entire sky, but I have not as yet made out the exact figures to indicate this. They do not, I think, exceed 20 per cent. of the stars on the whole, if they amount to that, but I suspect that more than one-half of the nearer stars possess this type of spectrum.

I remain, sincerely yours, W. H. S. Monck.

IS THE SUN BECOMING COLDER OR HOTTER?

[By Sir WILLIAM THOMSON, LL. D., F. R. S., F. R. S. E., etc., etc. (now Lord KELVIN).]*

"The question, Is the sun becoming colder or hotter? is an exceedingly complicated one, and in fact, either to put it or answer it, is a paradox, unless we define exactly where the temperature is to be reckoned. If we ask, How does the temperature of equi-dense portions of the sun vary from age to age? the answer certainly is, That the matter of the sun of which the density has any stated value, for example, the ordinary density of our atmosphere, becomes always less and less hot, whatever be its place in the fluid, and whatever be the law of compression of the fluid, whether the simple gaseous law, or anything from that to absolute incompressibility. But the distance inwards from the surface at which a constant density is to be found diminishes with shrinkage, and thus it may be that at constant depths inward from the bounding surface the temperature is becoming higher and higher. This would certainly be the case if the gaseous law of condensation held throughout, but even then the effective radiational temperature, in virtue of which the sun sheds his heat outwards, might be becoming lower, because the temperatures of equi-dense portions are clearly becoming lower under all circumstances.

"Leaving now these complicated and difficult questions to the scientific investigators who are devoting themselves to advancing the science of solar physics, consider the easily understood question, What is the temperature of the centre of the sun at any time, and does it rise or fall as time advances? If we go back a few million years, to a time when we may believe the sun to have been wholly gaseous to the centre, then certainly the central temperature must have been augmenting; again, if, as is possible though not probable at the present time, but probably will be the case at some future time, there be a solid nucleus, then certainly the central temperature would be augmenting, because the conduction of heat outwards through the solid would be too slow to compensate the augmentation of pressure due to augmentation of gravity in the

* The following pages are reprinted from Volume II of Sir WILLIAM THOMSON'S *Popular Lectures and Addresses*, Nature Series, 1891—a work whose every page is stamped with genius. They are extracts from a lecture delivered before the Royal Institution of Great Britain, January 21, 1887. *Ex pede Herculem.*

shrinking fluid around the solid. But at a certain time in the history of a wholly fluid globe, primitively rare enough throughout to be gaseous, shrinking under the influence of its own gravitation and its radiation of heat outwards into cold surrounding space, when the central parts have become so much condensed as to resist further condensation greatly more than according to the gaseous law of simple proportions, it seems to me certain that the early process of becoming warmer, which have been demonstrated by LANE, and NEWCOMB, and BALL, must cease, and that the central temperature must begin to diminish on account of the cooling by radiation from the surface, and the mixing of the cooled fluid throughout the interior.

"Now we come to the most interesting part of our subject—the early history of the sun. Five or ten million years ago he may have been about double his present diameter and an eighth of his present mean density, or .175 of the density of water; but we cannot, with any probability of argument or speculation, go on continously much beyond that. We cannot, however, help asking the question, What was the condition of the sun's matter before it came together and became hot? It may have been two cool solid masses, which collided with the velocity due to their mutual gravitation; or, but with enormously less of probability, it may have been two masses colliding with velocities considerably greater than the velocities due to mutual gravitation. This last supposition implies that, calling the two bodies A and B for brevity, the motion of the centre of inertia of B relatively to A, must, when the distances between them was great, have been directed with great exactness to pass through the centre of inertia of A; such great exactness that the rotational momentum, or "moment of momentum," after collision was no more than to let the sun have his present slow rotation when shrunk to his present dimensions. This exceedingly exact aiming of the one body at the other, so to speak, is, on the dry theory of probability, exceedingly improbable. On the other hand, there is certainty that the two bodies A and B, at rest in space, if left to themselves undisturbed by other bodies and only influenced by their mutual gravitation, shall collide with direct impact, and therefore with no motion of their centre of inertia, and no rotational momentum of the compound body after the collision. Thus we see that the dry probability of collision between two neighbors of a vast number of mutually attracting bodies widely scattered through space is much greater

if the bodies be all given at rest, than if they be given moving in any random directions and with any velocities considerable in comparson with the velocities which they would acquire in falling from rest into collision. In this connection it is most interesting to know from stellar astronomy, aided so splendidly as it has recently been by the spectroscope, that the relative motions of the visible stars and our sun are generally very small in comparison with the velocity (612 kilometres per second) which a body would acquire in falling into the sun, and are comparable with the moderate little velocity (29.5 kilometres per second) of the earth in her orbit round the sun.

"To fix the ideas, think of two cool solid globes, each of the same mean density as the earth and of half the sun's diameter, given at rest, or nearly at rest, at a distance asunder equal to twice the earth's distance from the sun. They will fall together and collide in exactly half a year. The collision will last for half an hour, in the course of which they will be transformed into a violently agitated incandescent fluid mass flying outward from the line of the motion before the collision, and swelling to a bulk several times greater than the sum of the original bulks of the two globes.* How far the fluid mass will fly out all around from the line of collision it is impossible to say. The motion is too complicated to be fully investigated by any known mathematical method; but with sufficient patience a mathematician might be able to calculate it with some fair approximation to the truth. The distance reached by the extreme circular fringe of the fluid mass would probably be much less than the distance fallen through by each globe before the collision, because the translational motion of the molecules constituting the heat into which the whole energy of the original fall of the globes becomes transformed in the first collision, takes probably about three-fifths of the whole amount of that energy. The time of flying out would probably be less than half a year, when the fluid must begin to fall in again towards the axis. In something less than a year after the first collision the fluid will again be in a state of maximum crowding round the centre, and this time probably even more violently agitated than it was immediately after the first collision; and it will again fly outward, but this time axially towards the places whence the two globes fell. It will again fall inwards, and after a rapidly

* Such incidents seem to happen occasionally in the Universe. [New or Temporary Stars are examples.]

subsiding series of quicker and quicker oscillations it will subside, probably in the course of two or three years, into a globular star of about the same mass, heat and brightness, as our present sun, but differing from him in this, that it will have no rotation.

"We suppose the two globes to have been at rest when they were let fall from the mutual distance equal to the diameter of the earth's orbit. Suppose, now, that instead of having been at rest they had been moving transversely in opposite directions with a relative velocity of two (more exactly 1.89) metres per second. The moment of momentum of these motions round an axis through the centre of gravity of the two globes perpendicular to their lines of motion, is just equal to the moment of momentum of the sun's rotation round his axis. It is an elementary and easily proved law of dynamics that no mutual action between parts of a group of bodies, or of a single body, rigid, flexible, or fluid, can alter the moment of momentum of the whole. The transverse velocity in the case we are now supposing is so small that none of the main features of the collisions and the wild oscillations following it, which we have been considering, or of the magnitude, heat and brightness of the resulting star, will be sensibly altered; but now, instead of being rotationless, it will be revolving round once in twenty-five days and so will be in all respects like to our sun.

"If instead of being at rest initially, or moving with the small transverse velocities we have been considering, each globe had a transverse velocity of three-quarters (or anything more than 0.71) of a kilometre per second, they would just escape collision, and would revolve in ellipses round their common centre of inertia in a period of one year, just grazing each other's surface every time they came to the nearest points of their orbits.

"If the initial transverse velocity of each globe be less than, but not much less than, 0.71 of a kilometre per second, there will be a violent grazing collision, and two bright suns, solid globes bathed in flaming fluid, will come into existence in the course of a few hours, and will commence revolving round their common centre of inertia in long elliptic orbits in a period of a little less than a year. Tidal interaction between them will diminish the eccentricities of their orbits, and if continued long enough will cause the two to revolve in circular orbits round the centre of inertia with a distance between their surfaces equal to 6.44 diameters of each.

"Suppose now, still choosing a particular case to fix the ideas,

that twenty-nine million cold, solid globes, each of about the same mass as the moon, and amounting in all to a total mass equal to the sun's, are scattered as uniformly as possible on a spherical surface of radius equal to one hundred times the radius of the earth's orbit, and that they are left absolutely at rest in that position. They will all commence falling towards the centre of the sphere, and will meet there in two hundred and fifty years, and every one of the twenty-nine million globes will then, in the course of half an hour, be melted, and raised to a temperature of a few hundred thousand or million degrees centigrade. The fluid mass thus formed will, by this prodigious heat, be exploded outwards in vapor or gas all round. Its boundary will reach to a distance considerably less than one hundred times the radius of the earth's orbit on first flying out to its extreme limit. A diminishing series of out-and-in oscillations will follow, and the incandescent globe thus contracting and expanding alternately, in the course it may be of three or four hundred years, will settle to a radius of forty times* the radius of the earth's orbit. The average density of the gaseous nebula thus formed would be (215×40), or one six hundred and thirty-six thousand millionth of the sun's mean density; or one four hundred and fifty-four thousand millionth of the density of water; or one five hundred and seventy millionth of that of common air at an ordinary temperature of 10° C. The density in its central regions, sensibly uniform through several million kilometres, is one twenty thousand millionth of that of water; or one twenty-five millionth of that of air. This exceedingly small density is nearly six times the density of the oxygen and nitrogen left in some of the receivers exhausted by BOTTOMLEY in his experimental measurements of the amount of heat emitted by pure radiation from highly heated bodies. If the substance were oxygen, or nitrogen, or other gas or mixture of gases simple or compound, of specific density equal to the specific density of our air, the central temperature would be 51,200° C, and the average translational velocity of the molecules 6.7 kilometres per second, being $\sqrt{\frac{3}{7}}$ of 10.2, the velocity acquired by a heavy body falling unresisted from the outer boundary (of forty times the radius of the earth's orbit) to the centre of the nebulous mass.

* The radius of a steady globular gaseous nebula of any homogeneous gas is forty per cent. of the radius of the spheric surface from which its ingredients must fall to their actual positions in the nebula to have the same kinetic energy as the nebula has.

"The gaseous nebula thus constituted would in the course of a few million years, by constantly radiating out heat, shrink to the size of our present sun, when it would have exactly the same heating and lighting efficiency, but no motion of rotation.

"The moment of momentum of the whole solar system is about eighteen times that of the sun's rotation; seventeen-eighteenths being *Jupiter's* and one-eighteenths the sun's, the other bodies being not worth taking into account in the reckoning of moment of momentum.

"Now instead of being absolutely at rest in the beginning, let the twenty-nine million moons be given each with some small motion, making up in all an amount of moment of momentum about a certain axis, equal to the moment of momentum of the solar system which we have just been considering; or considerably greater than this, to allow for effect of resisting medium. They will fall together for two hundred and fifty years, and though not meeting precisely in the centre as in the first supposed case of no primitive motion, they will, two hundred and fifty years from the beginning, be so crowded together that there will be myriads of collisions, and almost every one of the twenty-nine million globes will be melted and driven into vapor by the heat of these collisions. The vapor or gas thus generated will fly outwards, and after several hundreds or thousands of years of outward and inward oscillatory motion, may settle into an oblate rotating nebula extending its equatorial radius far beyond the orbit of *Neptune*, and with moment of momentum equal to or exceeding the moment of momentum of the solar system. This is just the beginning postulated by LAPLACE for his nebular theory of the evolution of the solar system; which, founded on the natural history of the stellar universe, as observed by the elder HERSCHEL, and completed in details by the profound dynamical judgment and imaginative genius of LAPLACE, seems converted by thermodynamics into a necessary truth, if we make no other uncertain assumption than that the materials at present constituting the dead matter of the solar system have existed under the laws of dead matter for a hundred million years. Thus there may be in reality nothing more of mystery or of difficulty in the automatic progress of the solar system from cold matter diffused through space, to its present manifest order and beauty, lighted and warmed by its brilliant sun, than there is in the wind-

ing up of a clock and letting it go till it stops.* I need scarcely say that the beginning and maintenance of life on the earth is absolutely and infinitely beyond the range of all sound speculation in dynamical science. The only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life.

"I shall only say in conclusion:—Assuming the sun's mass to be composed of materials which were far asunder before it was hot, the immediate antecedent to its incandescence must have been either two bodies with details differing only in proportions and densities from the cases we have been now considering as examples; or it must have been some number more than two—some finite number—at the most the number of atoms in the sun's present mass, a finite number (which may probably enough be something between 4×10^{57} and 140×10^{57}) as easily understood and imagined as numbers 4 or 140. The immediate antecedent to incandescence may have been the whole constituents in the extreme condition of subdivision—that is to say, in the condition of separate atoms; or it may have been any smaller number of groups of atoms making minute crystals or groups of crystals—snowflakes of matter, as it were; or it may have been lumps of matter like macadamising stone; or like this stone (Fig. 50 omitted), which you might mistake for a macadamizing stone, but which was actually travelling through space till it fell on the earth at Possil, in the neighborhood of Glasgow, on April 15th, 1804; or like that (Fig. 51 omitted), which was found in the Desert of Atacama, in South America, and is believed to have fallen there from the sky—a fragment made up of iron and stone, which looks as if it had solidified from a mixture of gravel and melted iron in a place where there was very little of heaviness; or this splendidly crystallised piece of iron (Fig. 52 omitted), a slab cut out of the celebrated aërolite which fell at Lenarto, in Hungary; or this wonderfully shaped specimen (Figs. 53 and 54 omitted), a model of the Middlesburgh meteorite (kindly given me by Professor A. S. HERSCHEL), having corrugations showing how its melted matter has been scoured off from the front part of its surface, in its final rush through the earth's atmosphere when it was seen to fall on March 14th, 1881, at 3.35 P. M.

* Even in this, and all the properties of matter which it involves, there is enough, and more than enough, of mystery to our limited understanding. A watch-spring is much farther beyond our understanding than is a gaseous nebula.

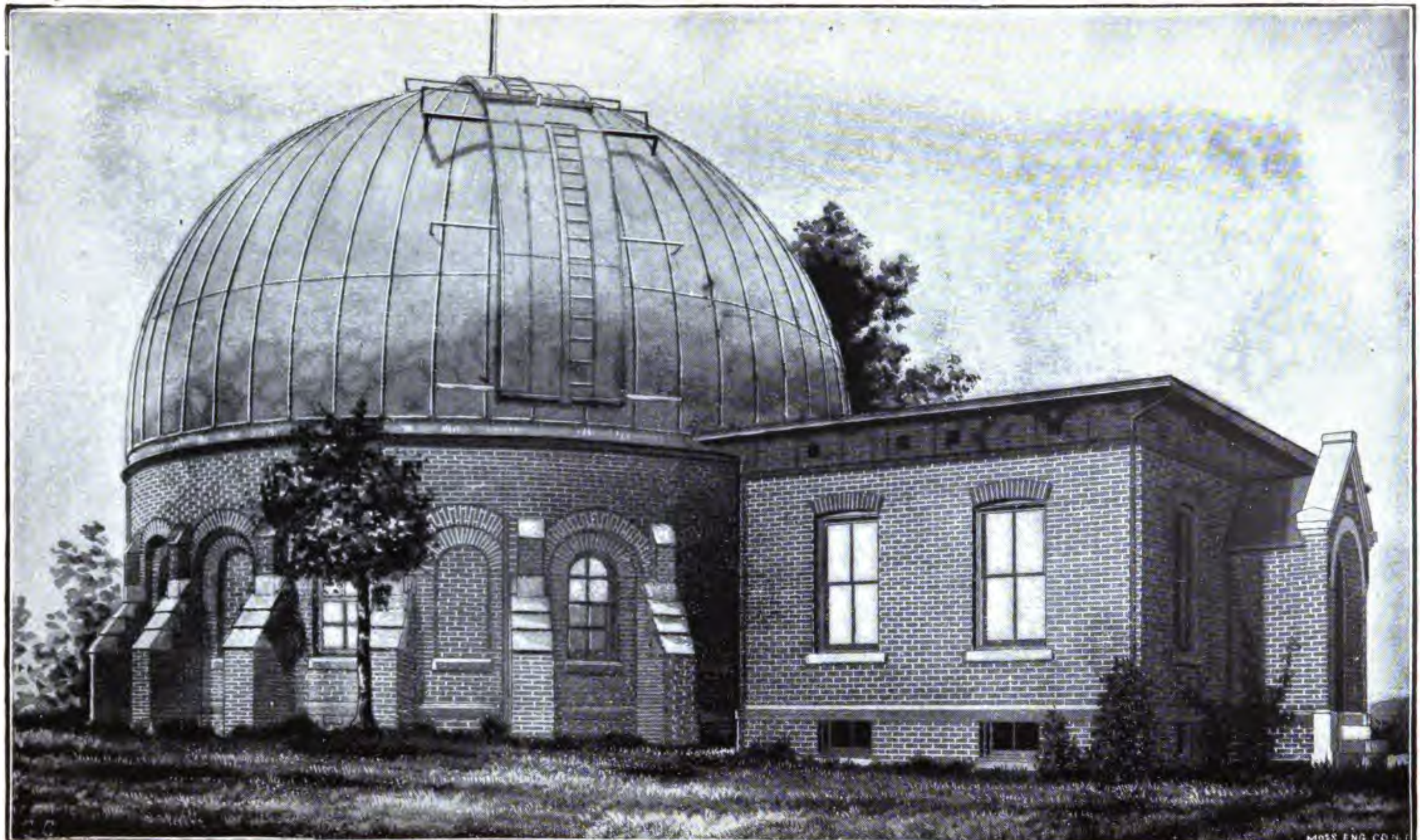
"'For the theory of the sun it is indifferent which of these varieties of configurations of matter may have been the immediate antecedent of his incadescence, but I can never think of these material antecedents without remembering a question put to me thirty years ago by the late Bishop EWING, Bishop of Argyll and the Isles; 'Do you imagine that piece of matter to have been as it is from the beginning; to have been created as it is; or to have been as it is through all time till it fell on the earth?' I had told him that I believed the sun to be built up of meteoric stones, but he would not be satisfied till he knew or could imagine what kind of stone. I could not but agree with him in feeling it impossible to imagine that any one of such meteorites as those now before you has been as it is through all time, or that the materials of the sun were like this for all time before they came together and became hot. Surely this stone has an eventful history, but I shall not tax your patience by trying just now to trace conjecturally. I shall only say that we cannot but agree with the common opinion which regards meteorites as fragments broken from larger masses, and we cannot be satisfied without trying to imagine what were the antecedents of those masses."

THE LEANDER McCORMICK OBSERVATORY.*

By H. A. SAYRE.

The LEANDER MCCORMICK Observatory is situated on the summit of Mt. Jefferson, at an altitude of about 850 feet above the level of the sea. At the base of the mountain, a mile away, lies the University of Virginia. On the site of the present observatory there once stood a small one, erected in the early days of the university, but afterwards abandoned. The instruments were preserved and are now in the physical laboratory. The present observatory and instruments are the gift of Mr. LEANDER J. MCCORMICK, a citizen of Chicago, but a native of Virginia. Through the active efforts of Col. C. S. VENABLE, Professor of Mathematics in the university, the endowment, sufficient to place the observatory on a sound basis, was secured. In 1885 the

* The woodcut which accompanies this paper we owe to the kindness of Dr. W. T. HARRIS, U. S. Commissioner of Education, Washington, D. C.



McCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA.

observatory was turned over to the university authorities. The engraving gives a view of the building from the east. In the dome is placed the CLARK 26-inch equatorial. Attached to the dome are two rooms, which are occupied by the computers and contain the library, clocks, chronograph and other instruments. The dome was constructed by Messrs. WARNER & SWASEY, of Cleveland, Ohio, and is 45 feet in diameter. Its weight above the wheels on which it rests is 25,000 pounds. It revolves on a live ring of wheels in sets of three; the centre ones of which support the dome, while the two outer ones rest on circular tracks. Two guide wheels, connecting with each set of wheels, one in front and one behind, run between the tracks of the wall plate. Sliding friction is changed to rolling friction by having the guide wheels so adjusted that the axis of the conical wheels is at right angles to the track at that point. A pull of about eight or ten pounds on the rope will move the dome, which has been rotated through an entire revolution in less than a minute. There are three apertures, six feet wide, with closures six feet square between. This arrangement ensures rapid ventilation. The object-glass made by ALVAN CLARK & SONS is 26 inches in diameter, and has a focal length of 32½ feet.

The inner surfaces of the lenses are made with slightly different radii in order to avoid the "object-glass ghost" found so annoying in many great telescopes. The tube which is of steel is in three sections. The micrometer wires and reading circles are illuminated by incandescent lamps fed by a small bichromate battery. The driving-clock is electrically connected with a SETH THOMAS clock in the computing-room.

In a smaller building near by are a 4-inch equatorial made by KAHLER and a 3-inch transit made by FAUTH & CO., of Washington. The library as yet is small but additions are constantly being made. Professor STONE was at first assisted by Mr. F. P. LEAVENWORTH, now Director of the Haverford College Observatory. His present assistant is Mr. N. M. PARRISH. The Director is also Professor of Astronomy in the university and Editor of the "Annals of Mathematics." The observatory has been devoted largely to the micrometrical determination of the positions of nebulæ. Incidentally a large number of sketches has been made, and several hundred new nebulæ have been detected. The various condensations in the central portion of the Nebula of *Orion* have been compared photometrically. Similar

observations have been made of the variable stars in the Huygenian region. Besides these and various miscellaneous observations, measurements of several hundred close southern double-stars have been made. In addition to contributions to the American Astronomical Journal, the Sidereal Messenger and the Annals of Mathematics, the following series of publications has been issued in pamphlet form by the observatory:

1. Transit of *Venus*, December 6, 1882.
2. Tail of Comet 1882, II.
3. Nebula of *Orion*, 1885.
4. Double Stars, 1885–86.
5. Durchmusterung, − 23°.

THE LUNAR CRATER *COPERNICUS*.*

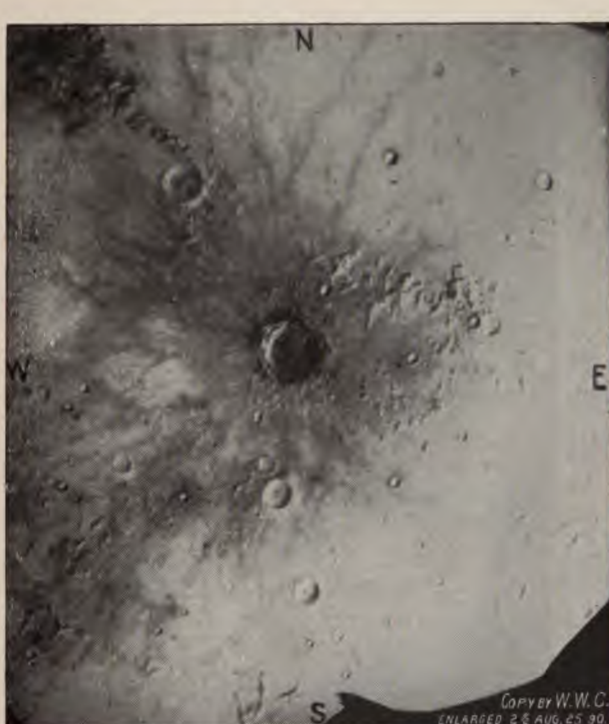
By Edward S. Holden.

The accompanying small figure was made from a negative of the moon taken in the focus of the great telescope on August 25, 1890, at 8 hours, 0 minutes. The original picture of the moon was about five and one-half inches in diameter. A small part of the original showing the lunar crater *Copernicus* has been slightly enlarged and is given in the cut. The scale of the picture is such that the diameter of the whole moon would be about fourteen inches. The diameter of the crater itself is fifty-six miles. The cardinal points, north, south, etc., are indicated on the picture. The original picture is very satisfactory. The representation given here is far less so, but it is the best available. It will probably serve its purpose, however. The other cuts are not enlarged, and show, more or less satisfactorily, the surroundings of this crater.

The walls of the ring-form are not perfectly circular, and they vary somewhat in height at different points.

Their general elevation above the floor of the crater is about eleven thousand feet, rising in places to twelve thousand or even thirteen thousand feet. The slope of the interior terraced wall is far more steep than that of the exterior; and this is a general rule in all such formations on the moon. The average exterior slope

* Reprinted (abridged) from the Californian Magazine, March, 1892.



THE LUNAR CRATER COPERNICUS.

Enlarged from a Negative made with the Great Telescope of the Lick Observatory, August 25, 1890.

of lunar craters is six degrees to seven degrees, while the average interior slope is thirty-five degrees; that is, they are really very gently sloped mounds with a steep-sided pit in the midst. The terraces of the walls deserve careful attention; and, if the cut is examined with a common hand-magnifier, they can be seen a little better.

The floor of the crater is by no means smooth; and from it rise two groups of central peaks, the highest of which is some twenty-four hundred feet. Like all the central peaks of lunar craters, they are much lower than the bounding walls.

Copernicus is surrounded by a mass of mountains, hills and ridges of highly complex structure, and by a marvelous system of brilliant streaks radiating from the crater as a center, and extending in some cases for four hundred miles, or even more, till they meet similar streaks from other craters,—from *Kepler*, *Aristarchus*, etc., which are shown on the cuts following.

This famous lunar mountain has been drawn and described many times. The very best drawings show a number of minor features which are much too small to be represented in the engraving; but no drawing has ever given anything like the true plastic effect, and even the very best drawings fail to show details which are evident on the original photograph.

To make such a drawing at the telescope, the observer must begin by sketching in the forms and shadows accurately, correcting here and adding there, until after one or two nights a skeleton for his finished picture is obtained. By this time the shadows have so changed that most of the work must be put by for a month, until the same phase of illumination recurs.

The next opportunity must be devoted to more corrections and additions, and so on, lunation after lunation, until finally the best possible result is attained. For instance, SCHMIDT'S first recorded observation of *Copernicus* was in 1842 and his last in 1873. And even this best possible result will be highly unsatisfactory. If it is a map it will lack plastic effect; if it is a picture the minor topographical features will necessarily be more or less neglected. It is here that photography becomes of priceless advantage. The preparations for the photograph must be made with the greatest care; the picture must be taken when the atmosphere is steady, clear and transparent; when there is no wind to shake the telescope. But when the right opportunity occurs an exposure of a few tenths of a second is sufficient; and a perma-

nent autographic record of things as they are is obtained. The negative can then be treated in many ways and many differing copies obtained, each one true in itself, but each one bringing out some one point with especial clearness. In the first place it can be enlarged so as to bring out the minor features. It can be "en-smalled" so as to sacrifice the minor details, while the grander relations are made more prominent. Each of these results can again be copied in various manners. A certain exposure given to the copy will produce the best general plastic effect, and it is such copies that are desired by the artist and the general reader. But every single feature on the original has an illumination and a distinctness of its own. If we double or treble, etc., the first exposure, or if we halve it or take a third or even a tenth part of it in making our copies, each of the results will show some special feature or region or relation in a new and in a true light.

In this way the negatives of the Lick Observatory have brought out quite new features,—ruined craters fifty miles in diameter, long streaks and ridges, not suspected or even not perceptible in ordinary visual observation. The key of this method is that the *contrasts* can be artificially (photographically) increased.

If the reader will look at Figure 1 once more, he can probably follow the following identifications. The numbers in parenthesis are the diameters of the craters in miles.

The prominent crater about three-fourths of an inch south of *Copernicus* (56), is *Reinhold* (31), and the next marked feature in the same direction is the crater *Landsberg* (28). Between *Reinhold* and *Copernicus* are two small deep crater-pits close together, A and A[1]. These are, by the way, *precisely* south of the center of *Copernicus*.

The crater half an inch north of *Copernicus* is *Gay-Lussac* (15); and the mountains in which the latter is situated are the lunar *Carpathians*, whose peaks vary from twenty-five hundred to seven thousand feet in altitude. Towards the northwest, about an inch in the picture, is the ring-crater *Eratosthenes* (37). From *Eratosthenes* two spurs of mountains extend, one southwards to the white outlines of the ring-crater *Stadius* (43), the other northwestwards. The region bordering these two spurs and lying towards the southeast is the *Sinus Æstuum*. The eastern wall of *Eratosthenes* is 7,450 feet above the outer surface, and 15,800 feet (the height of Mt. Blanc) above the interior of the crater.

S

PHOTOGRAPH OF THE MOON.

Made with the Great Telescope of the Lick Observatory, August 31, 1890, at 14h. 27m. Moon's Age, 16 days 18 hours.

On the original it is easy to trace a very interesting line of confluent crater-pits, which extends from the southeastern wall of *Stadius* towards the north; this line crosses the direction of the *Carpathians* about half way from *Eratosthenes* to *Gay-Lussac.*

Here then is a line of weakness, and along this line there have been many separate small explosions, each leaving its mark in a crater. The region between this line and the western wall of *Copernicus* is literally filled with such small craters (they cannot be seen in the picture because they are only visible under one particular illumination). They are somewhat like the *fumeroli* of Italian volcanoes, on a larger scale.

The preceding description is necessary to put us in possession of the facts which our picture shows. But the real question now comes: What is the veritable explanation of all this? How shall we conceive to ourselves the process by which these features were formed? What is the relation of these craters to each other; of these bright streaks to the central crater; of the mountain chains, the rows of crater-pits, the interior terraces and hills to the volcanic forces by which they have been created?

If these questions can be answered we shall really know something of the features which so far we have merely viewed. Notwithstanding the immense pains which have been spent in delineations of the particularities of this and other regions of the moon's surface, there is as yet no general and satisfactory answer. We seem to be awaiting some observer who must be at once an astronomer and a geologist, and who will devote his whole life to the geology of the moon. Even the most fundamental questions are not settled. We have called *Copernicus* a "crater," that is, *the* crater of a lunar volcano. Some of the best authorities doubt whether it is a true crater at all.

As with this, so with other questions. Many, indeed most of them, are in doubt; and it is certain that they will not all be definitely settled until the advent of our geologist-astronomer, who may not yet be born.

Under these circumstances, it will not be impertinent if I try to express the convictions to which my own observations of this particular region have led me, especially if I do this with the necessary reserves, and with an apology in advance for any failures to properly interpret the geological evidence. No one can examine these wonderful structures without forming *some* idea as to their nature, and my own is somewhat as follows:

In the first place it is obvious at a glance that *Copernicus* is the dominating feature in the landscape. The surrounding ridges, crater-pits and bright streaks radiate from and depend on this central crater precisely as the corresponding features depend upon *Mauna Loa*. Its vast mouth (56 miles in diameter) is, in fact, a crater,—one crater, or rather a caldera. Sometime in the past, vast explosions of steam and lava have blown out this immense cavity and left these bounding walls somewhat as they are now. We must recollect that the volcanic forces on the moon have been far more violent than they are now on the earth. We have to remember too that the surface of the moon as we see it in this picture is but a single phase of the history of this landscape. There were other volcanoes at this place centuries before *Copernicus* was formed, some of which can even now be traced; and we are only looking at the very last act of a long drama. Underneath the floor of *Copernicus* pipes were leading directly to the living fires below; and the interior lavas were continually rising and falling in these pipes, seeking for outlets through cracks in the mountain side, along lines of weakness everywhere, even overflowing the rim of the crater at times. When the level of the lava in the interior was high it would overflow the floor of the crater and would soon cool. If another vent was found at a lower level, through a crack in the mountain side, the lava in the pipes would sink and leave the floor unsupported except at its edges where it joined the walls. In time the floor would break off all around the rim and fall, leaving a terrace to mark its former position. A new rise of lava in the pipes would form a new floor, and this in turn would form a new terrace. Hundreds of these may have been formed, and scores of them may have left no trace; but the terraces we now see are, it seems to me, indubitable proof that this process went on in *Copernicus* almost precisely in the same way that it is even now going on in *Kilauea* in the Sandwich Islands.

There have been scores and scores of central mountains formed within the crater (just as at *Kilauea*). Those that we see now are the last ones. They undoubtedly contain volcanic vents, and at the very end of the volcano's history they poured a sheet of lava over the whole floor of the crater and left it comparatively smooth as it now is.

The original negative shows ridges streaming off in all directions from the outer walls of the crater. Some of these have been

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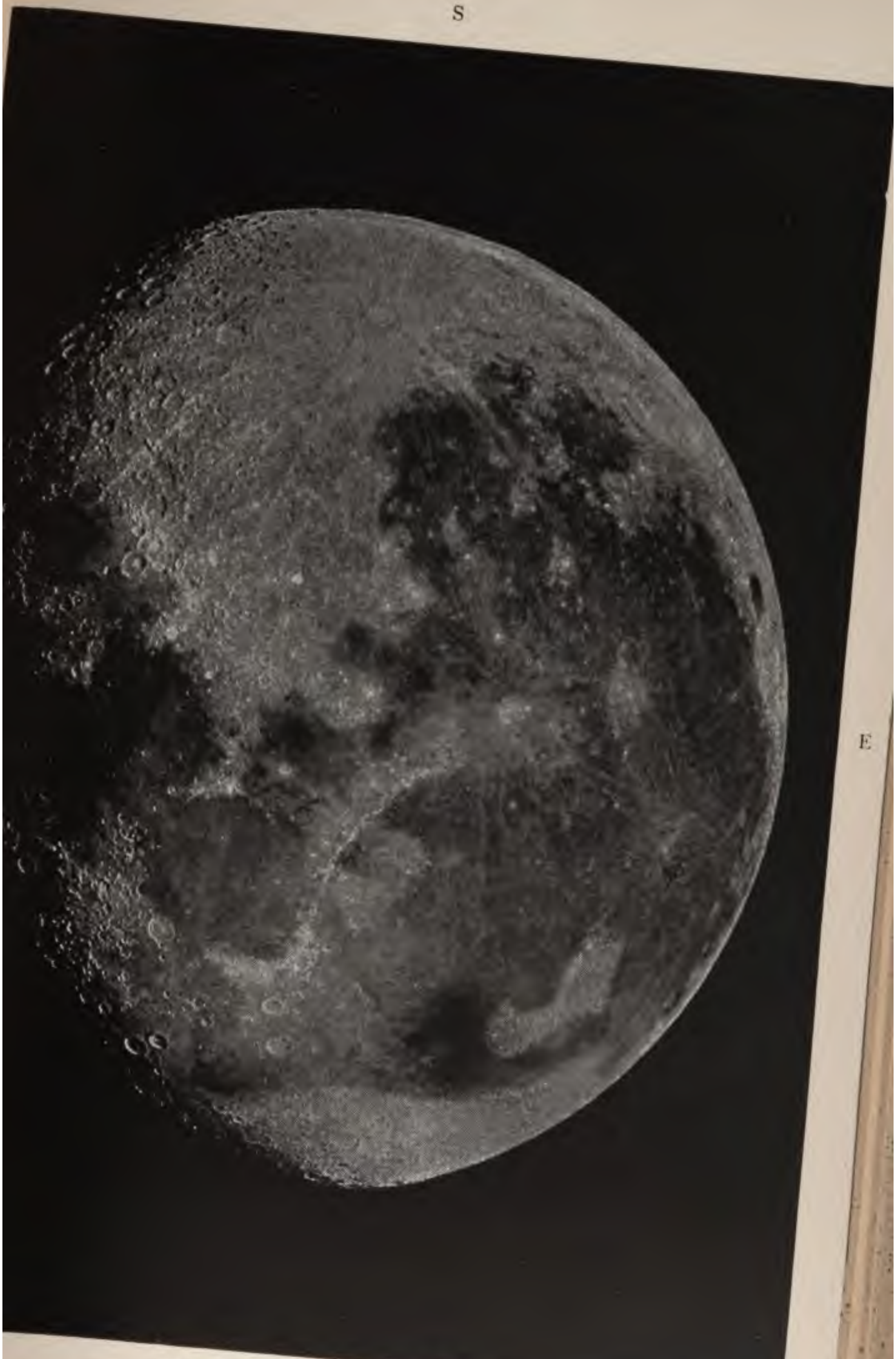

E

PHOTOGRAPH OF THE MOON.
Made with the Great Telescope of the Lick Observatory, August 24, 1888.
Moon's Age, 17 days.

formed by elevations of the surface by forces from below, and some of them by lava flowing over the lip of the crater itself, or through cracks in its sides. The bright radiating streaks near *Copernicus* are intimately connected with these ridges. Sometimes the streaks themselves seem to be nothing but very low ridges. In other places they seem to be lava flows which have partially filled up ravines lying between two ridges, or which have followed the direction of earthquake cracks and fissures, forming dikes.

When one is riding across country in the beautiful island of Hawaii and comes to some region which is not covered by dense tropical forests or by luxuriant sugar plantations, his attention is sure to be directed to one of the wonderful lava flows from the great volcanoes of *Mauna Loa* and *Mauna Kea*. He asks his guide, "What is this?" "Oh, this is the lava flow of 1852." Directly he comes to another river of frozen lava,—"And what is this?" "This is the flow of 1881." And so on till in a few days' journey he has crossed a dozen flows all radiating from the central mountain like rivers, all tending towards the sea, and some of them actually reaching it. Now, in Hawaii, history begins with the advent of the missionaries (1820). The larger part of the island is covered with forest and plantation, and therefore is hidden from sight. The action of wind and rain and air disintegrates the lava into soil with amazing quickness; and yet it is impossible for the traveler not to carry away in his mind a picture—a ground plan—of the island as it really is. Here is the central volcanic focus, and the lavas from its interior have built up the whole island mass. On the top of the older lavas, which are carved into ravines and cañons by erosion, lie the radiating lava streams which go in all directions from the center, and which extend even to the sea (thirty-five to forty-five miles). Here are the earthquake cracks and fissures filled up with later lava flows. Here are long tunnels whose broken-down tops leave marked channels,—streaks. Here are rows of confluent crater-pits of all sizes. Here are larger craters like *Kilauea* with subordinate ones like *Kilauea-iki*. Here are huge cracks in the mountain sides where the pressure of the interior lava has broken through.

I do not think that these bright streaks in the moon are volcanic ashes; for I see no reason why they should lie in radiating streaks as they do, unless *all* the streaks were in the bottoms of the cañons, which they are not, as visual observations show.

Again, volcanic ashes should lie in general on the *leeward* side; and I see no evidence that they are not equally distributed. Within the craters are the successive terraces, marking successive levels of the lava flow. The level of the floor of *Kilauea* is to-day more than four hundred feet higher than it was fifty years ago. Some of the older terraces are now submerged, and new ones are in process of formation. Here are the interior cones and mountain masses. In fact every feature which we see in the crater *Copernicus* seems to have its analogue if not its counterpart on this small island of Hawaii.*

If I am straining the analogies, I beg the pardon of my confrères, the geologists;—and I am aware that one of the very best observers of lunar topography has stated most emphatically that such an explanation as this will not serve. It, nevertheless, seems to me to be the true one for the region we are considering, while it certainly will not explain other phenomena of a *somewhat* similar character on other parts of the moon. Such analogies will surely strike any astronomer who travels in Hawaii. The only serious question to my mind is in regard to the difference in scale. In Hawaii we have central craters or *calderas* of two and three miles in diameter, and lava-flows from them of forty miles long which would be much longer if they did not end in the sea. On the moon we have the *caldera* of *Copernicus*, which is fifty-six miles in diameter, with lava-flows of four hundred miles or so. Having regard to the immensely greater effect of volcanic forces on the moon (where the force of gravity, for example, is not more than one-sixth of that on the earth), I confess that I see nothing overstrained in drawing the conclusion that in the volcanoes of Hawaii we now have before our eyes something like a working model of what *Copernicus* once was.

This, then, is what seems to me to be the key to the landscape shown in our engraving; and it gives a kind of unity to its complex confusion and wild variety. There are other regions on the moon far more difficult to understand; but here, at least, it seems that a kind or order can be made to arise out of the chaos.

* I think it is very pertinent to remark that the lavas of Hawaii are much more liquid than those of Italy, for example; and it seems almost safe to hazard the guess that the lavas of the Moon resemble the former rather than the latter.

S

PHOTOGRAPH OF THE MOON.

Made with the Great Telescope of the Lick Observatory, November 3, 1890, at 13h. 58m.
Moon's Age, 21 days 5 hours.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. IV. SAN FRANCISCO, CALIFORNIA, JUNE 11, 1892. NO. 24.

THE ASTRONOMICAL EXHIBIT AT THE WORLD'S COLUMBIAN EXPOSITION.

BY GEORGE E. HALE.

The four hundredth anniversary of the discovery of America by COLUMBUS is to be fittingly celebrated at Chicago in 1893. In buildings which themselves sufficiently emphasize the progress of American architectural skill, the exhibits of the world will be so grouped as to render evident to the visitor the gradual development and the present condition of every art, science and industry. Only those who have recently visited the grounds of the Exposition, and watched the daily progress achieved by an army of nearly five thousand laborers, can have any adequate idea of the exalted standard of excellence which the directors have in view. Some of the buildings are practically completed, and it is already possible to faintly picture the Venice-like beauty which the waters of Lake Michigan and the winding lagoons will lend to the scene. But it is not with the evidence of material progress that we are now dealing. It is of more interest to learn that a space nearly 800 feet long and 300 feet wide has been set apart in the largest and best situated building on the grounds for the use of the department of Liberal Arts, and in this space the astronomical exhibit will naturally be found.

The scope and nature of this exhibit will largely depend on the liberality with which astronomers and instrument-makers respond to the call for a full and complete display. Advices already received from WARNER & SWASEY, J. A. BRASHEAR and ALVAN CLARK indicate that there will be no lack of instruments of the highest class. It is hoped that there will be at least one refracting telescope of fully 20 inches aperture, and among a number of

smaller refractors it is probable that two will exceed an aperture of 12 inches. Reflectors will be shown in all sizes, while the mere fact that BRASHEAR will exhibit is a sufficient guarantee that spectroscopes of all kinds, gratings, prisms, flat surfaces, etc., will not be lacking. Two large domes have been arranged for, and a model of the Lick Observatory is now being made at Mount Hamilton. As many apparatus makers are yet to be heard from, the outlook in this direction is most encouraging.

The great advances in astronomy and spectroscopy which have resulted from the application of photography should be fully illustrated. At the Lick Observatory a large number of transparencies on glass, eight by ten inches in size, are being prepared from negatives of the moon, *Jupiter*, etc., and the remarkable success of the HENRY DRAPER Memorial will no doubt be exemplified by a large collection of photographs of the stars and stellar spectra from the Harvard College Observatory. It is to be hoped that Professor ROWLAND will send many specimens from the extensive series of photographs of solar and metallic spectra on which he is now engaged.

It is also proposed to include in the exhibit a collection of photographs of all telescopes in the United States of six inches aperture and upwards, together with all important spectroscopes and special instruments employed in astronomical or spectroscopic investigation. It is desirable that the photographs should be, so far as possible, of the uniform size of eight by ten inches. They may be either glass transparencies, or *unmounted* paper prints. The latter will be properly mounted by those who have charge of the installation.

Finally a large collection of American astronomical publications is desired. These will include complete sets of the publications of observatories and societies; periodicals; books and papers on astronomy and spectroscopy, etc.

It will be noticed that only American exhibits are here called for. The arrangements of the 52 foreign countries which have officially announced their intention of participating in the Exposition are such that the exhibits will be grouped by nations, rather than by subjects. While this natural system may possess some disadvantages as compared with a rigid classification by subjects, it will at the same time have the corresponding advantage of stimulating national pride. If, as we hope, every foreign country will give as much attention to the astronomical as to an industrial

exhibit, the United States will need to look to her laurels. An *adequate* representation of our part in the progress of astronomy would undoubtedly substantiate our claim to an important position among the nations engaged in the advancement of research.

THE WORLD'S CONGRESS AUXILIARY OF THE WORLD'S COLUMBIAN EXPOSITION.*

DEPARTMENT OF SCIENCE AND PHILOSOPHY. GENERAL DIVISION OF MATHEMATICS AND ASTRONOMY.

Preliminary Address of the General Committee of the World's Congress Auxiliary on Mathematics and Astronomy.

GEORGE W. HOUGH, LL. D., Chairman.

The World's Congress Auxiliary is an organization maintained by the World's Columbian Exposition, and approved by the Government of the United States, for the purpose of organizing a series of Congresses or Conventions to be held during the progress of the Exposition in 1893, and which will bring together the leading scholars of the world for the mutual interchange of ideas on topics bearing on human progress.

A Scientific Congress to present and consider investigations in its special lines of research from all parts of the world, cannot fail to exert an important influence in the progress of scientific development. The personal interchange of views in regard to methods of observation and investigation will undoubtedly be productive of mutual benefit to the members of the Congress, as well as of lasting value to science.

The General Committee on Mathematics and Astronomy presents this Preliminary Address, cordially inviting the co-operation of all persons and societies interested in this department of physical science.

As the matter assigned to this Committee covers a large field in Physical Science, it has been thought advisable to arrange the subjects to be considered under the following Chapters and Sections, in which in consideration of its recent development and

* Printed by request. The lists of members of the "Advisory Councils" have been omitted.

growing importance, Astro-physics has been assigned a separate Chapter from other branches of general Astronomy.

The following are some of the topics suggested for consideration under the several Chapters:

CHAPTER I.—PURE MATHEMATICS.

Section a. History and Bibliography.
Section b. Arithmetic and Theory of Numbers.
Section c. Analysis.
Section d. Geometry.
Section e. Analytical Mechanics.
Section f. Mathematical Physics.

CHAPTER II.—ASTRONOMY.

Section a. History of Astronomy.
Section b. Astronomical Instruments.
Section c. Methods of Observation.
Section d. Physical Astronomy.
Section e. Observatory Buildings.

CHAPTER III.—ASTRO-PHYSICS.

Section a. Spectrum Analysis.
Section b. Astronomical Photography.
Section c. Stellar Photometry.

The object of this Preliminary Address is simply to bring the subject of the Congress to the notice of the scientific men of the world for advice and suggestions as to the general conduct of the convention, and in particular as to the scientific questions to be discussed. Recommendations of themes to be discussed and of persons to present them are especially solicited from the members of the Advisory Council of the Astronomical Congress. The Advisory Councils constitute the non-resident branches of the Auxiliary Committees. Additions to these Councils will be made from time to time. Communications may be addressed to the Chairman of the General Committee, or to the Chairman of the proper Special Committee.

It is expected that men eminent in special lines of research will be invited to furnish papers on the leading topics under consideration. The suggestions and recommendations invited will be used in the formation of the programme for the Congress.

The Chairman of the Special Committees of the several Chapters under the charge of the General Committee, are as follows:

On Pure Mathematics—Prof. E. H. MOORE, Chicago University, Chicago, Ill.

On Astronomy—Prof. G. W. HOUGH, Dearborn Observatory, Northwestern University, Evanston, Ill.

On Astro-physics—Prof. GEO. E. HALE, Kenwood Astro-physical Observatory, Chicago, Ill.

GEO. W. HOUGH, Chairman.
ELIAS COLBERT, Vice-Chairman.

E. H. MOORE,	R. W. PIKE,
GEORGE E. HALE,	GEO. C. COMSTOCK,
G. A. DOUGLASS,	W. W. PAYNE.
MALCOLM MCNEILL,	

Committee of the World's Congress Auxiliary on a Congress of Mathematicians and Astronomers.

WORLD'S CONGRESS HEADQUARTERS,
CHICAGO, March, 1892.

THE BRITISH ASTRONOMICAL ASSOCIATION.

The British Astronomical Association was formed in October, 1890, for the purpose of securing the co-operation of astronomical observers throughout the country, and at the same time to meet the wishes and requirements of many who, though interested in astronomy, have found themselves precluded by one cause or another from joining the Royal Astronomical Society. It numbers already upwards of seven hundred members of whom more than one hundred are resident in the colonies and foreign countries, the United States in particular furnishing a numerous and distinguished contingent. A large number of ladies have also availed themselves of the advantages of the Association and become members and many regularly attend the meetings.

Thirteen Sections have already been formed, under experienced directors, for the purpose of organized and systematic work in the various departments of astronomical research. They are as follows: *Solar*, *Solar Spectroscopic*, *Lunar*, *Jupiter*, *Saturn*, *Mars*, *Cometary*, *Colored*, *Variable and Double Stars*, *Stellar Spectroscopic*, *Meteoric and Photographic.*

Ten numbers of the Journal of the Association are published each Session. The first volume forms an illustrated book of 600 pages, and contains, in addition to the papers read before the Association, notices and abstracts of all the principal astronomical publications of Europe and America. Memoirs on special subjects are also issued from time to time.

The headquarters of the Association are in London, and the meetings are held monthly, on the last Wednesday in the month, from October to June inclusive.

Provision has been made for the formation of branches in the Provinces and abroad, and one Provincial Branch is already in successful operation.

The Association possesses a valuable loan collection of Astronomical Lantern Slides and a library is in course of formation.

The terms of membership, which is open to all interested in astronomy, ladies as well as gentlemen, are entrance fee 5*s*., annual subscription 10*s*. 6*d*., or life members a single payment of £6. 6*s*. and entrance fee. The subscription entitles members to receive all the publications of the Association post free, and in the case of members joining after commencement of a Session to the back numbers of that Session.

Enquiries should be addressed to either of the Secretaries,

ARTHUR COTTAM, F. R. A. S., Eldercroft, Watford,
P. F. DUKE, F. R. A. S., Henden, Middlesex;

or to the Assistant Secretary,

THOS. FRID MAUNDER, 26 Martin's Lane,
Cannon Street, London, E. C.

(EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Dr. LEWIS SWIFT, Director of the WARNER Observatory, Rochester, New York, for his discovery of an unexpected comet on March 6.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER.

May 6, 1892.

(NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific, has been awarded to W. F. DENNING, Esq., F. R. A. S., of Bristol, England, for his discovery of an unexpected comet on March 18.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER.

May 18, 1892.

A HANDBOOK OF PRACTICAL ASTRONOMY FOR UNIVERSITY STUDENTS AND ENGINEERS.

By W. W. CAMPBELL, Ann Arbor, 1891, 8vo, 166 + iii pp.

[Reviewed by Prof. J. E. KEELER, Director of the Allegheny Observatory.]

For an undergraduate course of instruction in practical astronomy the larger and complete works of CHAUVENET and others are much too elaborate, as their thorough reading would require more time than can usually be allotted to the subject of astronomy. It is the usual practice of the teacher to omit certain portions of the text-book, and no doubt the result is fairly satisfactory, but a course arrived at by such a process of exclusion is necessarily inferior in logical coherence to one specially prepared in accordance with a systematic plan. In the latter case the student is not embarassed by frequent references to matter in omitted chapters, formulae required in practice are readily found, —and other advantages will readily suggest themselves.

Mr. CAMPBELL's book contains an abridged course in practical astronomy which is admirably adapted to the requirements of the undergraduate student who wishes a general preparation for further and more special work, and to those of students of civil engineering, who desire a complete treatment of certain practical problems. The instruments and methods in common use in observatories are fully explained, while special instruments like the heliometer, and unusual methods of observation with ordinary instruments, are omitted. The instruments selected for

a sufficiently complete treatment are the sextant, transit, zenith telescope, and equatorial, with the minor appliances used in connection with them. The meridian circle is omitted, probably on account of the considerable amount of space it would require.

The essential formulae of spherical astronomy are developed in the first five chapters. In mathematical treatment, CHAUVENET and other standard authorities are generally followed, and their familiar notation is retained, which is an excellent feature of the book. Numerous examples are given in illustration, mostly from observations made at the Detroit Observatory. It is to be especially remarked that constant reference is made to the Nautical Almanac so that the student, after completing his course, should be perfectly familiar with it uses.

A chapter on the surveyor's transit considered as an altitude and azimuth instrument for astronomical work will be very useful to surveyors and engineers, as it shows how to determine azimuths, latitude, and time to within the least angle that can be read on the graduated circles of the instrument.

Among the novelties which have hitherto not found their way into text-books, we notice SCHAEBERLE'S method of adjusting the polar axis of an equatorial. For large instruments, in particular, this method is simpler and more convenient in its application than the usual one. The practical character of the book as a guide to the student in the art of observation is shown by the attention paid to minor details of methods, which the beginner is apt to regard as unimportant, but in the observance of which really lies all the difference between good and indifferent work. A good point is made in avoiding negative readings in determining the index correction of a sextant, as they are a fruitful source of error to the inexperienced observer.

An appendix contains some valuable hints on computing, a collection of formulae for the adjustment of observations by the method of least squares, a short list of teloscopic objects, the Pulkowa refraction tables, and a table of reductions to the meridian and to elongation.

With the exception of a few geometrical diagrams, the book is not illustrated, but as it is intended to be used in the observatory, with the instruments themselves before the student, the lack of more elaborate figures will not be felt.

VERY BRIGHT METEOR OBSERVED MAY 20, 1892.

Mr. ZIEL writes from Alameda:—"On Friday night, May 20, at $9^h\ 30^m$, I saw a bright meteor in the northwestern sky; it was *much* brighter than *Venus*." [A diagram of its path is given: the body passed between *Castor* and *Pollux* going downwards in a direction towards *Venus*.]

RESIDUALS OF RECENT OBSERVATIONS OF μ^2 *HERCULIS*.

BY ARMIN O. LEUSCHNER.

Elements of μ^2 *Herculis* were published by Prof. CELORIA of the *Brera Observatory* at Milan in vol. cxxiii, no. 2949 of the *Astr. Nachr.*, giving a period of 40.65 years. Shortly after my own elements appeared in the *Publ. A. S. P.*, vol. ii, p. 46, the period being 45.39 years. The date of the last observations upon which these orbits are based is 1888.63 (SCHIAPARELLI) for the former and 1889.51 (BURNHAM) for the latter. Since then Prof. HALL, of the U. S. Naval Observatory, has published a series of measures in vol. x, no. 16, of the *Astronomical Journal*, covering the period from 1880 to 1891, and Prof. BURNHAM, of the Lick Observatory, has observed the companion regularly every year. It will be of considerable interest to know how the elements represent these observations. The residuals of some of Prof. HALL'S measures have already been printed with the elements, but of a few of them values were used in the determination of the elements which are slightly different from those last printed in the *Astronomical Journal*. For this reason as well as to keep these residuals together they have been recomputed and are included in the table below.

The very last observations seem to indicate that the periods arrived at are too short, although the period of 45 years cannot be much out. The discrepancies are not large enough to warrant an attempt at improvement of the elements at present, and as the motion is becoming less rapid now, probably several years will have to elapse before much can be gained by correcting the elements.

The residuals here given were obtained by comparison of the observations with an ephemeris computed for both orbits from the elements, the position-angles and distances being calculated for the beginning of each year. These residuals have a much higher degree of accuracy than those printed with the elements in *Publ. A. S. P.*, vol. ii, p, 47, which were obtained approximately from the interpolating curve.

The fourth and seventh columns below contain the corrections (p) for precession which must be added to the observed position-angles in the second column in order to reduce them to 1889.0 and 1888.0 to which dates the orbits are referred. The residuals are taken in the sense observation *minus* computation.

Places are predicted for both orbits up to 1895.0, the columns headed (p) giving the corrections to the observations for precession.

Prof. BURNHAM who kindly made his last set of measures at my request adds that *they are good observations and should represent the relative positions with fair accuracy.*

Astronomers will confer a favor upon me by communicating to me any unpublished measures of μ^2 *Herculis* which they may have in their possession, or by calling attention to other observations already published, but not included in the determination of either orbit.

EPOCH.	θ_o	ρ_o	CELORIA. p	CELORIA. $\theta_o-\theta_c$	CELORIA. $\rho_o-\rho_c$	LEUSCHNER. p	LEUSCHNER. $\theta_o-\theta_c$	LEUSCHNER. $\rho_o-\rho_c$	OBSERVER.
	°	″	°	°	″	°	°	″	
1880.654..	246.28	1.005	−0.05	−0.2	−0.08	+0.00	+0.9	−0.06	Hall.
1881.548..	249.08	1.008	−0.05	−2.1	−0.04	+0.01	−0.9	−0.02	Hall.
1882.524..	259.12	0.702	−0.04	+2.4	−0.29	+0.02	+3.6	−0.26	Hall.
1883.584..	262.93	0.663	−0.03	−1.0	−0 23	+0.02	+0.3	−0.21	Hall.
1884.643..	273.37	0.650	−0.03	+0.4	−0.13	+0.03	+1.6	−0.10	Hall.
1885.559..	288.03	0.610	−0.02	+4.7	−0.07	+0.03	+5.7	−0.04	Hall.
1886.596..	300.12	0.386	−0.01	+1.1	−0.20	+0.04	+1.5	−0.17	Hall.
1887.577..	321.47	0.423	−0.01	+3.1	−0.11	+0.05	+3.0	−0.09	Hall.
1888.634..	341.45	0.388	0.00	±0.0	−0.14	+0.05	−0.1	−0.13	Hall.
1889.51 ..	357.9	0.55	0.00	−0.8	−0.03	+0.06	−0.5	−0.03	Burnham.
1889.651..	0.62	0.345	0.00	−0.5	−0.25	+0.06	±0.0	−0.25	Hall.
1889.73 ..	359.1	0 52	0.00	−3.4	−0.08	+0.06	−2.8	−0.08	Burnham.
1890.38 ..	9.4	0.66	+0.01	−2.8	−0.01	+0.07	−1.8	−0.01	Burnham.
1890.552..	13.22	0.512	+0.01	−1.3	−0.18	+0.07	−0.1	−0.18	Hall.
1891.38 ..	18.5	0.72	+0.01	−5.3	−0 06	+0.07	−3.6	−0.07	Burnham.
1892.37 ..	28.8	0.89	+0.02	−3.3	−0.02	+0.08	−1.1	−0.02	Burnham.

Predicted Places.

Epoch.	Celoria, 1889.0.				Leuschner, 1880.0.			
	θ	Diff.	p	ρ	θ	Diff.	p	ρ
	°		°	"	°		°	"
1892.00.....	29.31		+0.02	0.86	27.34		+0.08	0.86
		1.97				1.83		
.25.....	31.28			0.89	29.17			0.90
		1.83				1.70		
.50.....	33.11			0.92	30.87			0.93
		1.71				1.59		
.75.....	34.82			0.95	32.46			0.96
		1.61				1.49		
1893.00.....	36.43		+0.03	0.98	33.95		+0.08	0.99
		1.51				1.39		
.25.....	37.94			1.01	35.34			1.02
		1.42				1.31		
.50.....	39.36			1.04	36.65			1.05
		1.35				1.24		
.75.....	40.71			1.07	37.89			1.08
		1.29				1.17		
1894.00.....	42.00		+0.03	1.10	39.06		+0.09	1.11
		1.22				1.11		
.25.....	43.22			1.13	40.17			1.14
		1.15				1.05		
.50.....	44.37			1.15	41.22			1.17
		1.10				1.00		
.75.....	45.47			1.18	42 22			1.20
		1.07				0 97		
1895.00.....	46.54		+0.04	1.20	43.19		+0.09	1.23

Berkeley, Cal., June 4th, 1892.

A REPETITION OF FOUCAULT'S PENDULUM EXPERIMENT.

By Torvald Köhl, of Denmark.*

On the 12th and 22d of April I made a public trial of Foucault's Pendulum Experiment in the Cathedral of Aarhus. The pendulum had a length of 21.1 metres (69.22 feet) and weighed 35 kilogrammes (77.17 lbs. avoirdupois), the cylinder being of lead. The steel wire was fastened above to an iron frame, in the upper part of which the end of a small cone served as the point of suspension of the pendulum; the cone resting in a depression made in an iron rod. The rod itself was placed across

* Translated for the Society by F. R. Ziel.

a hole in the arch of the cupola, the latter having a thickness of one foot and the hole being two inches in diameter. A sheet of paper, upon which a circle was drawn, was placed exactly under the point of the pendulum. As the hourly deviation for Aarhus (56° north latitude) amounts to very nearly 12°, two principal radii were drawn, forming an angle of 12° with each other. The radii were extended by means of chalk lines to a length of 57 inches, so that every degree of the circumference was just one inch long. Two burning candles were placed outside of the circle, in the prolongation of the radii, in order to show the deviation of the pendulum more distinctly. At the beginning of the experiment the point of the pendulum also passed through two layers of sand, placed on opposite sides of the circle.

As the thread was burned and the pendulum began to move, the organ commenced to intone and the audience of 200 people followed, with the greatest attention, the slow turning of the ground in reference to the undeviating plane of oscillation of the pendulum.

The pendulum made 13 oscillations in a minute, and when it had completed 65 oscillations its point showed exactly the calculated deviation of 1° towards the west. After an hour had elapsed the pendulum had just passed the 12th degree of the circle. Later on trials were made to ascertain what influence side currents of air would have on the movement of the pendulum, but although large plates were swung close to the pendulum, no effect upon the same could be detected. As it was also important to determine the value of the inertia, experiments were made with the gyroscope for that purpose.

THE RUTHERFURD PHOTOGRAPHIC MEASURES OF THE *PLEIADES.*

By Dr. W. L. Elkin,
Astronomer of the Observatory of Yale University.

The publication of the large collection of material contained in the Rutherfurd photographic plates, of whose value there can hardly now be two opinions, has been commenced by the Columbia College Observatory, and in an interesting paper (*Contributions from the Observatory of Columbia College*, No. 3),

Mr. HAROLD JACOBY has given us an account of the deductions of the results from ten plates of the *Pleiades* taken in 1872 and 1874.

The details of the measuring apparatus and the methods of measurement are to form a subsequent paper by Prof. REES, but starting from the measured distances and position-angles from a central star, Mr. JACOBY has applied all the apparently requisite corrections and deduced the relative places of 75 stars for the epoch 1873.0.

These corrections are briefly: (1) the division errors of the glass scales, which were determined by Prof. W. A. ROGERS; (2) the run of the micrometer-screw which gave the fine subdivision of the scale; (3) the correction for refraction, for which Mr. JACOBY has deduced very complete formulae for the case in which the data are the true distance and position-angle at the central star; and (4) the corrections for precession, nutation and aberration.

The scale-value was determined for each of the two impressions (exposures) on each plate by a comparison of the distances of six suitable stars from the central star with values found from the Königsberg and Yale measurements. While this process is probably sufficiently accurate, it is by no means exhaustive and it would have been of considerable interest to have compared *all* the measured distances with the heliometer values, and collated them with regard to possible effect of varying magnitude, distance and direction.

The position-angle zero was determined by means of an impression of the central star made after the star had been allowed to trail nearly off the plate. This is theoretically sound, but in practice it would seem difficult to prove that the telescope might not have slightly changed in declination in stopping and re-starting the clockwork.

Each plate was reduced with its own scale-value and position-angle zero, and no systematic corrections are applied to reduce to the mean result of all the plates. Mr. JACOBY shows, as is, however, almost self-evident, that if *all* the stars are measured on *all* the plates, the effect of such correction is finally, *nil.* This is very nearly the case for the series of plates in question and probably very slight changes would have been caused by applying this process.

The values for the reduced distances and position-angles for the several impressions, for the larger part of the stars, twenty in

number, show a close accordance and the average probable error of a distance-result was about $\pm 0''.18$, and that of a position-angle result about $\pm 0''.27$; this latter value being probably greater, as Mr. JACOBY remarks, on account of the more absolute character of the angles. An inspection of the tabulated values fails to reveal any larger discordances, such as might be attributed to distortion of the film, and there seems to be but one residual exceeding $1''$, for the distances, at least, except in the case of the last star (No. 75), which must have fallen very close to the edge of the plate. As every measure made has been utilized, this is very eloquent testimony to the stability of the albumen-collodion film and to the care taken in the manipulation of the plates.

The final test of the accuracy of the photographic results must lie in the comparison with those of other methods, whose accuracy can be estimated, and thus the comparison which Mr. JACOBY gives of the final concluded values with those of the heliometer is of especial interest.

Mr. JACOBY gives the differences of the photographic co-ordinates from values interpolated from the Königsberg and Yale measurements but does not deduce any criterion of accuracy beyond remarking that the photographic results agree quite as well with those of the heliometer as the two triangulations made at Yale agree *inter se*. This is quite true, but as the *differences* of the two Yale measurements are subject to probable errors of from $0''.15$ to $0''.27$, according to the magnitude of the stars, it is a little misleading as to the value of the photographic results, for which the residuals are given from what is very nearly the mean result of the Königsberg and the two Yale triangulations and are thus not far from expressing the accuracy of the photographic co-ordinates alone. I have thought it of some interest to compute the probable errors of the photographic co-ordinates from these residuals using the values derived in my *Pleiades* paper as to the accuracy of the heliometer results.

If ϵ_1 and ϵ_2 are the probable errors of a co-ordinate given by two measurements at the epochs t_1 and t_2, the probable error ϵ of a value interpolated for any epoch t may be derived from the expression

$$\epsilon^2 = \epsilon_0^2 + (\epsilon_1^2 + \epsilon_2^2)\left(\frac{t - t_0}{t_2 - t_1}\right)^2,$$

when

$$\epsilon_0^2 = \frac{\epsilon_1^2\ \epsilon_2^2}{\epsilon_1^2 + \epsilon_2^2} \text{ and } t_0 = \frac{t_1\,\epsilon_2^2 + t_2\,\epsilon_1^2}{\epsilon_1^2 + \epsilon_2^2}.$$

Adopting the values $\pm 0''.07$ and $\pm 0''.14$ for the two classes of the Königsberg work, and those on page 86 of my *Pleiades* paper for the second magnitude classes, we get the following table:—

Magnitude.	P. error of Königsberg Co-ordinates.	P. error of Yale Co-ordinates.	ϵ_0^2	t_0	ϵ for t = 1873.
	$''$	$''$			$''$
3.0 to 7.5	±0.07	±0.075	0.00262	1861.0	0.058
" "	0.14	0.075	437	1875.0	.066
7.6 8.1	0.14	0 080	483	1873.9	.070
8.2 8.8	0.14	0.099	652	1870.0	.081
8.9 9.2	0.14	0.135	944	1863.3	.106

The probable value of a residual $\Delta\alpha \cos\delta$ or $\Delta\delta$ as given by Mr. JACOBY I find to be for the several classes as follows, adding the probable error of a heliometer co-ordinate as just deduced and finally the probable error of a photographic co-ordinate as found from combining the two sets of values:—

Magnitude.	Prob. Residual.	Prob. Error of Hel. Co-ordinates.	Prob. Error of Photo. Co-ordinates.	No. of Stars.
	$''$	$''$	$''$	
3.0 to 7.5	±0.150	±0.058	±0.139	10
" "	152	0.066	.137	9
7.6 8.1	163	0.070	.147	14
8.2 8.8	186	0.082	.167	10
8.9 9.2	148	0.106	.103	5

Thus in the mean the photographic co-ordinates from the ten plates appear to be affected with a probable error of about $\pm 0''.14$. The accuracy of the heliometer values, for the bright stars, at least, has certainly not been over-estimated (see, for instance, BATTERMANN in *Astr. Nachr.*, No. 2926), and hence the photographic values appear to have suffered considerably from systematic error, as the probable error of a co-ordinate derived from their internal agreement is only $\pm 0''.05$ as against the value $\pm 0''.14$ just found from the heliometer companions.

I have plotted the residuals given by Mr. JACOBY and have come to the same conclusion as he did as to their not showing any systematic error of the photographic position-angles. On the other hand, however, there appears to be a marked deviation in the distance results, as for the smaller distances from the central star, say under 1500″, the photographic values are almost

without exception larger than the heliometer ones. And I should like to state that this is probably largely due to a systematic error in the heliometer method of measurement which makes the distances come out too small, and which Dr. GILL and myself have only recently traced to its source. When this is taken into account, as I propose to do shortly in a revision of the Yale *Pleiades* work, the accuracy of the photographic results will be still more apparent. It speaks not a little, meanwhile, for their reliability that they have not failed to show up this small but important inconsistency in the heliometer measures.

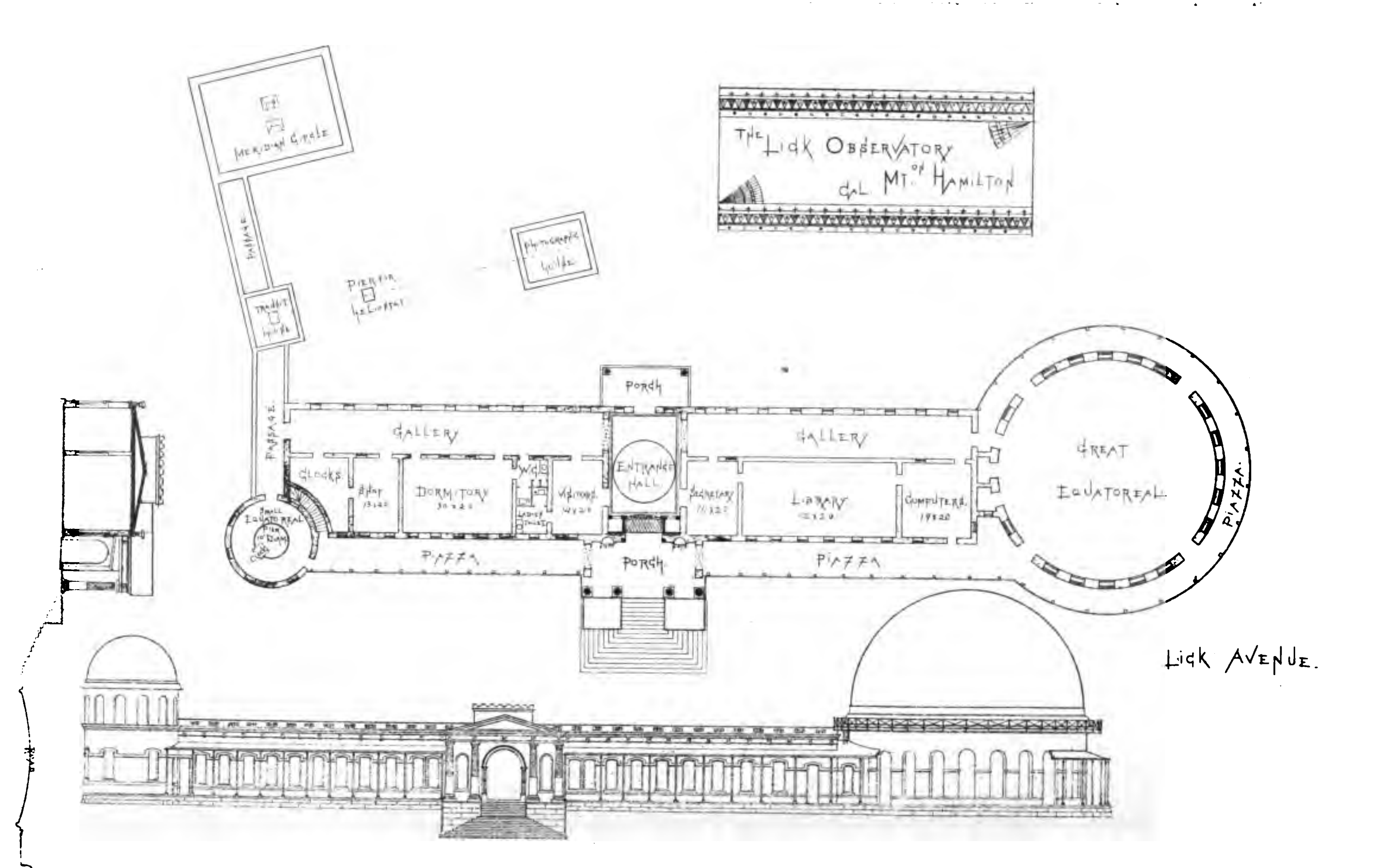
YALE UNIVERSITY OBSERVATORY,
May, 1892.

OBSERVATIONS OF THE SUN IN 1891 AND 1892.

BY MISS ROSE O'HALLORAN.*

With commendable zeal Miss ROSE O'HALLORAN of San Francisco has made observations of the sun spots on every favorable day since November, 1891. In the period of 152 days between November 1, 1891 and March 31, 1892, only 23 days were wholly cloudy; and during this time 70 maps of the solar surface were constructed. Forty-one distinct groups of spots were observed, 19 in the northern hemisphere and 22 in the southern. Bridges connecting different members of the group were very numerous and distributed in the two hemispheres in the same proportion as the spots. Isolated spots were very few. Only five spots were observed to be within 10° of the solar equator. A rapidly developing group of spots near the sun's western limb was observed and sketched on January 19. The return of this group was looked for on the eastern limb on February 3 and 4, and was first seen the afternoon of the 4th. This group was identical with the Great February Sun Spot Group; so that Miss O'HALLORAN was one of its very earliest observers, and possibly the earliest. It was followed closely until unfavorable weather prevented further observations. The observations were made with a 4⅛-inch BRASHEAR refractor, with powers of 50, 100 and 200.

* Abstract by W. W. CAMPBELL of a paper presented to the Society June 11, 1892, by Miss O'HALLORAN.



EARLY DESIGN FOR THE LICK OBSERVATORY.

NOTE ON THE EARLY HISTORY OF THE LICK OBSERVATORY.

By Edward S. Holden.

On July 16, 1874, Mr. Lick made his first deed of trust and appointed a Board of Trustees consisting of Messrs. Thomas H. Selby, D. O. Mills, H. M. Newhall, Geo. H. Howard, James Otis, John O. Earl and William Alvord. So much of this deed (subsequently annulled) as relates to the observatory is given in the *Publications* of the L. O., Vol. I, page 5.

In the summer of 1874 Mr. Mills visited Washington and consulted with Professor Newcomb and myself on the plans for the new institution. He also visited Dr. Henry Draper in New York for the same purpose. Before leaving Washington he requested me to prepare a brief memorandum to be presented to the trustees on his return to San Francisco. The memorandum was prepared (and is reprinted below with a few omissions) and it was accompanied by a ground plan of the proposed buildings. This sketch, by Professor Newcomb and myself, is now lost. Some of the pencil sketches from which it was made are, however, still in my possession. Essentially the same ideas were made the basis of a carefully drawn plan which was prepared for the (third) Board of Lick Trustees by Mr. S. E. Todd, architect, in Washington in 1879. This latter plan (which is practically the same as that of 1874) is reproduced in the accompanying plate. The observatory is now built substantially according to this plan simplified and made somewhat less costly, and at the same time less sightly.

The original plan of 1874 contemplated making a portion of the observatory building of two stories. Surveys made between 1875 and 1879 seemed to show that it would be advantageous to place all the principal rooms on the ground floor. The plan of 1879 was drawn with this modification of the original sketch of 1874. In the actual construction of the observatory it was found necessary to return to the first idea and to place some offices and a photographic laboratory on a second floor.

In the plate herewith the longest direction of the building is (magnetic) north and south with the Great Dome at the south end. The first office north of the dome is erroneously marked

"Computers." It was intended as the Director's office. It was intended to fit the quarters of the Senior Astronomers with studies so that much of their work would be done in their houses. The office of the Junior Astronomers is marked "Dormitory" in the architect's plan. The buildings were to be enlarged, when necessary, by constructing rooms on the east side opening into the long hall (marked "Gallery" in the plan). The continuous piazza of the first floor and the balcony at the base of the hemispherical dome, with the continuous platform on the roof leading to and opening into the small North Dome have been changed in the actual building, and the change has not been an improvement, I think.

In 1874 Mr. MILLS invited me to become the Director of the new observatory, and I accepted the offer. On his return to San Francisco he found that various difficulties had arisen between Mr. LICK and the Trustees. These were finally settled by the resignation of the first Board in 1875; and a second deed of trust was executed bearing date of April 21, 1875, and a second set of trustees was appointed, namely: Messrs. R. S. FLOYD, F. D. ATHERTON, JOHN H. LICK, JOHN NIGHTINGALE, B. D. MURPHY. Extracts from Mr. LICK'S second (and last) deed are given in the *Publications* L. O., Vol. I, page 9. The second set of trustees resigned in September, 1875, and the third (and last) Board was appointed at the same time, namely: Messrs. R. S. FLOYD, WM. SHERMAN, E. B. MASTICK, C. M. PLUM and GEO. SCHOENWALD.

In 1876 I met Captain FLOYD, the President of the Board, in London, and explained to him what was contained in the memorandum of 1874 which he had not then seen. The memorandum was at Mount Hamilton during the whole time of the building of the observatory and was in constant use. It is now lost. I have found the original *MS.*, dated October, 1874, from which the clean draft was made and I think it of sufficient interest to be reprinted here as a part of the early history of the observatory. It will show, I think, that one clearly conceived and consistent plan has been steadily followed from 1874 until the completion of the observatory in June, 1888.

It must be borne in mind, while reading it, that it was written nearly twenty years ago. The memorandum and plan herewith were submitted to Mr. LICK in his lifetime and I believe they were satisfactory to him.

MEMORANDUM ON THE FOUNDING OF THE LICK OBSERVATORY OF CALIFORNIA.*

I. Objects of the New Observatory (and Plan of Operations).

The object of the Lick Observatory has been announced by the founder himself in the deed conveying the funds necessary to complete it. This object is to establish a more powerful telescope than any now made, and to make the same "useful in promoting science." The object of, and excuse for, its existence is the promoting of astronomical science in general, and it at once becomes its duty to assume a class of observations for which either its geographical or climatic situation, its instrumental equipment, or its endowment, renders it peculiarly fitted.

We have in America several observatories which have assumed special work which they are doing satisfactorily. For example, the Naval Observatory has three meridian instruments, and six observers are employed with them; and they are engaged in cataloguing a number of fixed stars, and in making regular observations of the sun, moon and major planets, and a fair number of observations of the asteroids. The positions of stars determined by these instruments are not of the last degree of precision and there is no observatory in the United States engaged in making such determinations—hence it is evident that one of the works fairly open to the new observatory is the accurate determinations of the places of a number of standard stars, which shall serve astronomers as zero points from which to measure the coordinates of other stars. This work would be extremely valuable, but on account of its extreme delicacy and the multiplied precautions which would have to be taken in fixing these positions, this is work which would progress but slowly. It would require for its prosecution a meridian-circle, or else two instruments, the transit and the vertical circle (the meridian circle combines the principles of the other two). These should be of a good aperture (from five to six inches), and it is almost essential that whatever instrument of this class was employed should be made by the REPSOLDS of Hamburg or by TROUGHTON and SIMMS of London, who have unrivaled reputations, and whose finished instru-

* Copy of a Memorandum of October, 1874, sent to the President of the Lick Trustees by E. S. HOLDEN.

ments of this class are the best in the world. There need be no haste in the procuring and setting up of this instrument, and when it is completed it will require the exclusive attention of one observer. No meridian instrument of importance would be required, save a meridian-circle, or in the case of the adoption of the two instruments in its stead, a transit instrument and a vertical circle. A small portable transit instrument and a zenith telescope (combined) might well be added to the equipment of the observatory for immediate use in obtaining the geographical position of the site which will be selected, and the correct time for general daily use when the observatory shall be in operation, and before the final mounting of the meridian circle.

The meridian circle is admirably adapted to the rapid determination of the approximate position of small stars, *i. e.*, by using it in zone observations. The northern heavens from the pole to two (2) degrees south of the equator have been examined in this way by the great ARGELANDER, whose Zones have been published in three volumes, one comprising 108,129 stars, and extending to the pole to 41° of north declination; one of 105,075 stars, from 41° to 20°; and one of 110,984 stars, from 20° to —2°, thus making 324,188 stars catalogued in this region. The German Astronomical Society has undertaken the revision of this work, and hence it would be superfluous for the Lick Obseratory to attempt this, or any part of it. It might, however, do useful work in extending the zones southward, provided it did not duplicate any of the zone work just finished by the Observatory of Cordoba in the Argentine Republic.

This kind of work would require the co-operation of two observers, or of an observer and a recorder, and would demand their whole attention. Meridian observations of the sun, moon and planets it would not be advisable to undertake, these being thoroughly attended to at Greenwich and Washington. The observation of asteroids is not sufficiently attended to in America, but it would hardly be advisable for the Lick Observatory to make itself responsible for their continuous observation at present, although it might become a work worth undertaking.

To sum up the meridian work of the observatory, it seems that the only series of this kind which it is worth while at once to prepare for are the determinations of the position of fundamental stars and the continuation of the zones to the south.

The searching for new asteroids is thoroughly done by Prof.

WATSON of Ann Arbor and Dr. PETERS of Clinton, N.Y. They have extended and minute maps of all the small stars in certain portions of the heavens, and by a nightly examination of these maps they are at once able to say whether any new star has appeared in that region; and they have only to determine whether that new star is a new planet or merely a small star overlooked in their previous survey. The making of these extended maps is evidently the important thing in the search for asteroids, and it does not seem desirable that the new observatory should undertake the work of making over again the excellent maps of Dr. PETERS and Prof. WATSON (which maps, however, are at present kept secret by these two astronomers, but which one day will be published), or of looking for more new planets, the discovery of which in a scientific point of view does not seem to be very important (as 140 of these bodies are now known).

Besides the meridian work of an observatory and the work of the equatorials (which will be considered later), there are many problems of a physical nature which may be legitimately taken up. Among these none is more important, perhaps, than a regular photographic record of the spots which constantly appear on the sun's disc; the number of these spots varies from day to day, and the whole amount of "spotted area" varies in extent during a period of about eleven years, *i. e.*, a maximum spot area occurs about every eleven years. This period has been shown to have a definite relation to terrestrial magnetism (it is supposed likewise to be connected with temperature, rainfall and other terrestrial phenomena). A series of daily photographs of the sun, continued during the whole period of eleven to twelve years, would be of the greatest value, and this is a research which it is a duty of the new observatory to undertake; at Kazan in Russia, Greenwich in England, Toulouse in France, and at the new Sun Observatory to be established by the Russian Government, these observations will be made continuously. Professor LANGLEY of the Alleghany Observatory at Pittsburg also will probably commence a series of his own. At Harvard College Observatory this work is likewise done, although the continuity of the series is not complete. It is important that as many of these observations as possible should be made.

The instruments required for this purpose are inexpensive, comprising a photoheliograph, a large heliostat (not necessary for the sun photographs but necessary for photographs of star

clusters) together with a complete photographic laboratory. One assistant would be required, who would have to be not only an expert photographer but a man of high intelligence and of education. Besides a daily photograph of the sun, it would be the duty of the photographic assistant to make a series of photographs of star clusters which would have to be carefully measured to determine the relative position of the individual stars. These being once recorded, photographs taken at some future period will decide the question whether there has been any change in the configuration of this particular star group.

Experiments should be made to see if it is not possible to get good photographs of the brighter planets, *Jupiter*, *Venus*, *Saturn*, *Mars*. The photographing of the spectra of stars also will be a research which must be attempted.

The photographic assistant could likewise attend to the self-registering meteorological instruments which it will be necessary to have.

The equipment of the observatory in extra-meriodional instruments should be large. Beside the great equatorial, it may be well to have a smaller one, large enough to be of good light gathering power, and small enough for convenient and rapid handling say of from 12 to 15 inches aperture.

A comet seeker of about 5 to 6 inches aperture will be necessary for various minor works, such as the observation of eclipses of *Jupiter's* satellites, occultations, etc., for photometrical researches with the photometers of ZOELLNER or SEIDEL.

It is upon the work of the equatorial instruments that the force of the new observatory should be concentrated. The 12-inch or 15-inch equatorial should be exquisitely mounted, no possible pains being spared, and it should be one of the works to be soon taken up to determine, with this instrument, the parallax of some favorably situated stars. This instrument, and occasionally the large one, might well be devoted in the hands of Mr. BURNHAM, in case he should be appointed, to the steady observation of double stars, a department in which Mr. BURNHAM has already made so honorable a name. The large equatorial should, for the first years of its existence, be devoted to the observation of the outer planets and of their satellites, to stellar spectroscopy (the field of solar spectroscopy is already thoroughly worked) and to the spectroscopy and physical observation and drawing of nebulae. All ingenuity should be exhausted in the attempt to photograph a

nebula with the object of detecting change in one if it exists, and failing in that, it should be attempted to draw the nebulae by means of a modification of the Camera Lucida. The spectra of stars it is highly desirable to photograph and some success has already been achieved in this way by Dr. HENRY DRAPER. The great telescope might well be employed in this research.

It has been the desire, so far, to indicate to the Lick trustees in a very general and rough way the objects to which the new observatory should devote itself in the future in order for it to be most useful in "promoting science." The general principle of the selection of subjects for research being that it should devote itself peculiarly to those problems which are most unlikely to be studied by other observatories, and for which either its geographical or climatic situation, its instrumental means or endowment, render it most fit. In this connection it is well to remember that the situation of the observatory is likely to be in a country where volcanic, *i. e.*, earthquake phenomena often show themselves, and this makes it the duty of the new observatory to provide itself with self-recording instruments for indicating such phenomena. Similarly the experience gained by several years residence at the observatory will indicate the direction in which to extend its physical researches. Above all things, however, the object of concentration should be kept in view.

A certain line of action and a plan should be decided on, but these should be flexible, so that an extension may be easy and natural; but that work should be undertaken which can be done completely; and no more instruments should be purchased at first than can be kept busy. It must be remembered that the possession of the instruments implies obligation to make them useful, and again that they require great attention; so that a too complete instrumental equipment may become a burden and not a help.

II. Of the Government of the Observatory and its Officers.

The funds are by deed of Mr. LICK, put in charge of the Board of Trustees, and the financial concerns of the observatory are necessarily referred to them. All expenditures are of course controlled by them, but many expenditures may well be made by the Director, he being directly accountable to the Board of Trustees.

It is advisable in an undertaking of so much magnitude that any important scientific measures should be undertaken only after

due consideration and counsel, and it is respectfully proposed that the Trustees appoint a Scientific Council for the Observatory to be composed of four persons, all of whom should be connected with astronomical science in some honorable manner and most of whom should be men who have achieved for themselves scientific fame. It is suggested that the Board of Trustees could not select for this purpose four men more valuable to the interest of the Lick Observatory and more eminent as sponsors for a new scientific institution than the four gentlemen hereafter named.

1. Prof. JOSEPH HENRY, Secretary Smithsonian Institution.
2. Prof. J. H. C. COFFIN, U. S. Navy, Superintendent American Ephemeric and Nautical Almanac.
3. Prof. S. NEWCOMB, U. S. Navy.
4. Prof. HENRY DRAPER, University of New York.

The Director of the Observatory should be *ex officio* a member of this council, and he should consult with them in relation to the general management and work of the observatory proper. But the action of the council should be always subordinated to the authority of the Board of Trustees, the functions of the council being merely advisory. Vacancies in the council should be filled by appointment of the Board of Trustees.

Visits at suitable intervals should be made by the Scientific Council, or by some of its members, to the observatory; and a report of the activity of the Institution should be made to the Board of Trustees by the visiting members.

III. The Selection of the Site.

Certain general principles may be laid down with regard to this.

1st. It should be easily accessible and therefore not very far from some line of railroad. The reason for this is obvious.

2d. The astronomical conditions should be favorable. These are of a complex nature and extended experiments are necessary to determine what locality to select. Considerations, not only as to altitudes above the sea, but likewise as to steadiness of star images, moisture of the air, amount of yearly rainfall and more particularly of snowfall should be regarded. It seems advisable that when the Director is appointed, Mr. BURNHAM of Chicago should be asked to visit him for consultation, and that both of them be directed to proceed as soon as possible to California to visit the various localities which seem most favorable, there to examine

by means of Mr. BURNHAM'S 6-inch equatorial the astronomical conditions of all of the best sites. It is expected that no more than eight or ten such places will have to be examined. Some of them can be pronounced upon in a few days, some it will be necessary to visit twice. Only one person need *stay* in California on this duty, but all the sites should be examined by the Director, preferably as soon after he is appointed as possible.

The expenses of this journey need not be large, but a proper compensation should be paid to Mr. BURNHAM. A report of these operations should be made to the Board of Trustees.

IV. The Ideas which should Govern in the Procuring of the Rough Glass for the Great Equatorial,

have been proposed in writing by Prof. NEWCOMB and it is suggested that Prof. NEWCOMB be invited to go to Europe as soon as possible for the purpose of making a satisfactory contract with a proper firm for the casting of the glass in the rough. Instructions should be given him from the Board of Trustees as to his duties and power to act, and suitable experiments on the glass from various manufacturers should be first made; in Europe or in America as most convenient. The report of Prof. NEWCOMB to the Board of Trustees should be made in writing, and would become the property of the observatory.

With regard to the other instruments, it is suggested that as soon as the Director is appointed, he should be empowered to correspond with various optical instrument makers with the view of obtaining their prices and plans. It is suggested that if the 12-inch glass with which the CLARKS discovered the companion to *Gamma Lyrae* be still unsold that this will be a suitable one to buy. If not, then it is suggested that they be requested to make a 15-inch glass of excellent quality and first rate mounting; also a comet seeker of 6-inches aperture, mounted on an alt-azimuth.

With regard to the Meridian-circle it is suggested that its purchase be delayed till a careful consideration of its construction is had, with a view to improving on past instruments if this be possible. Prof. NEWCOMB might be empowered to order from the REPSOLDS while he is in Europe a portable transit instrument and zenith telescope combined.

The observatory would require at least three astronomical clocks and two or three break-circuit chronometers. The clocks, it would be well to order at once.

V. Of the Buildings of the Observatory.

Detailed plans of the observatory cannot be fully made until the dimensions of the large equatorial are known, but many of the general plans *can* be prepared. Some suggestions are here given.

1st. It is not at all desirable that any unnecessary expense be incurred in architectural ornament. The first object should be to prepare everything with reference to its use, and then to give the building such architectural effect as seems best without interfering with its utility.

The following rooms will be required:

1. Dome for large equatorial (detached building, or rather a wing of the observatory).
2. Dome for small equatorial (on top of observatory proper).
3. Photographic laboratory.
4. Machine shop (thoroughly equipped).
5. Fire-proof instrument room and record room, for spectroscopes, clocks, etc.
6. Library.

7, 8, 9. Offices on ground floor for Trustees, Director and Assistants.

10. Battery room for electric batteries (cellar).
11. Furnace room (cellar).

12, 13. 14. Store, coal or wood and engine room (cellar).

So that the cellar will contain:

1. Furnace room. 2. Store room. 3. Fuel room. 4. Battery room. 5. Engine room (small one-horse power caloric engine).

The first floor will have:

1, 2, 3. Offices for Trustees, Director, Assistants. 4. Porter's room also in small wings. 5. A clock room. 6. Workshop.

The second floor:

1. Large library room. 2 or 3 computing rooms.
4. Photographie laboratory.

On the roof will be a large tank of water kept full (to be mentioned hereafter) and also the dome for the 12-inch glass.

The transit-circle to be in an isolated building, and the photoheliograph to be in another. These are of wood and inexpensive.

The main building to be of brick painted, the workshop and clock-room fireproof, and the house for the Director to be on one side, that for the assistants on the other separated by these fireproof rooms from the observatory proper. (See plan herein enclosed.) South of the observatory proper to be a fireproof instrument and record room, thus isolating the observatory from

the dome. Every precaution should be taken and thus will be taken to protect the great telescope from fire, and it is evident that these precautions are necessary to guard so valuable a property.

I am in favor of making the frame work of the dome of iron instead of wood for the following reasons:

1st. It can be made *lighter*, when we consider the necessary size and strength. The dome of the Naval Observatory is not required to resist the weight of the snow, but the new dome must be able to do this, and for this reason the top part must be extra strong.

2d. It is not inflammable.

3d. It can all be made by skilled labor in the East, put together and then taken apart and set up in its place. A wooden dome ought to be made at the site.

4th. An iron dome can be made to keep an invariable shape; a large wooden dome must inevitably change a little; it *may* spring badly.

The only wood used in the construction of the dome would be small strips (which must be Burnetized) to which to fasten the galvanized iron which forms the outside of the dome, and likewise the floor. I would have an iron pipe of about two inches in diameter leading from the tank on the roof (or it might be elsewhere placed) to a point in the wall of the dome, a few inches above the floor. A valve should be placed in the end of this, so that in case the floor of the dome (the only inflammable portion of it according to my plan) should become ignited, it would be simply necessary to turn on the valve and in an instant the whole floor could be covered with several inches of water. Thus, I conceive there would be no possible danger of losing by fire the work of years, and I think this the more important as the new observatory will not be protected by steam fire engines as it would be in a city.

The houses of the officers of the observatory should be comfortable but inexpensive and convenient to the observing rooms. Experience has shown that in this way much more work is done.

The Library.—It is all important that in an isolated position free access to astronomical literature should be had, and the formation of a complete special library should be begun *at once.* Many of the books required are quite rare, and their collection requires that the orders for them should be given at once in order that they mav be obtained within a few years. A sum should be

immediately put at the disposal of the Director for the purpose, and Prof. NEWCOMB should be further empowered to order in Europe such as he may find. At the various observatories which he may visit, he will be presented with valuable sets of publications if he is authorized to secure them for the new observatory.

VI. The Personal Establishment might then at first consist of—

1. A Director, who would be executive head, and who would undertake regular observations.
2. A chief Astronomical Assistant. 3. An Astronomical Assistant.

These gentlemen would be employed on the Equatorials and Meridian Instruments.

4. A Photographic Assistant. 5. A Machinist. 6 and 7. Two laborers, who would serve as watchmen, helpers, etc.

In a general way, supposing the great telescope to cost $100,000, it may be said, that this observatory could be built and completely equipped for $250,000 to $275,000, including everything.* The yearly expenses would be about $25,000 and thus a large surplus will accumulate.

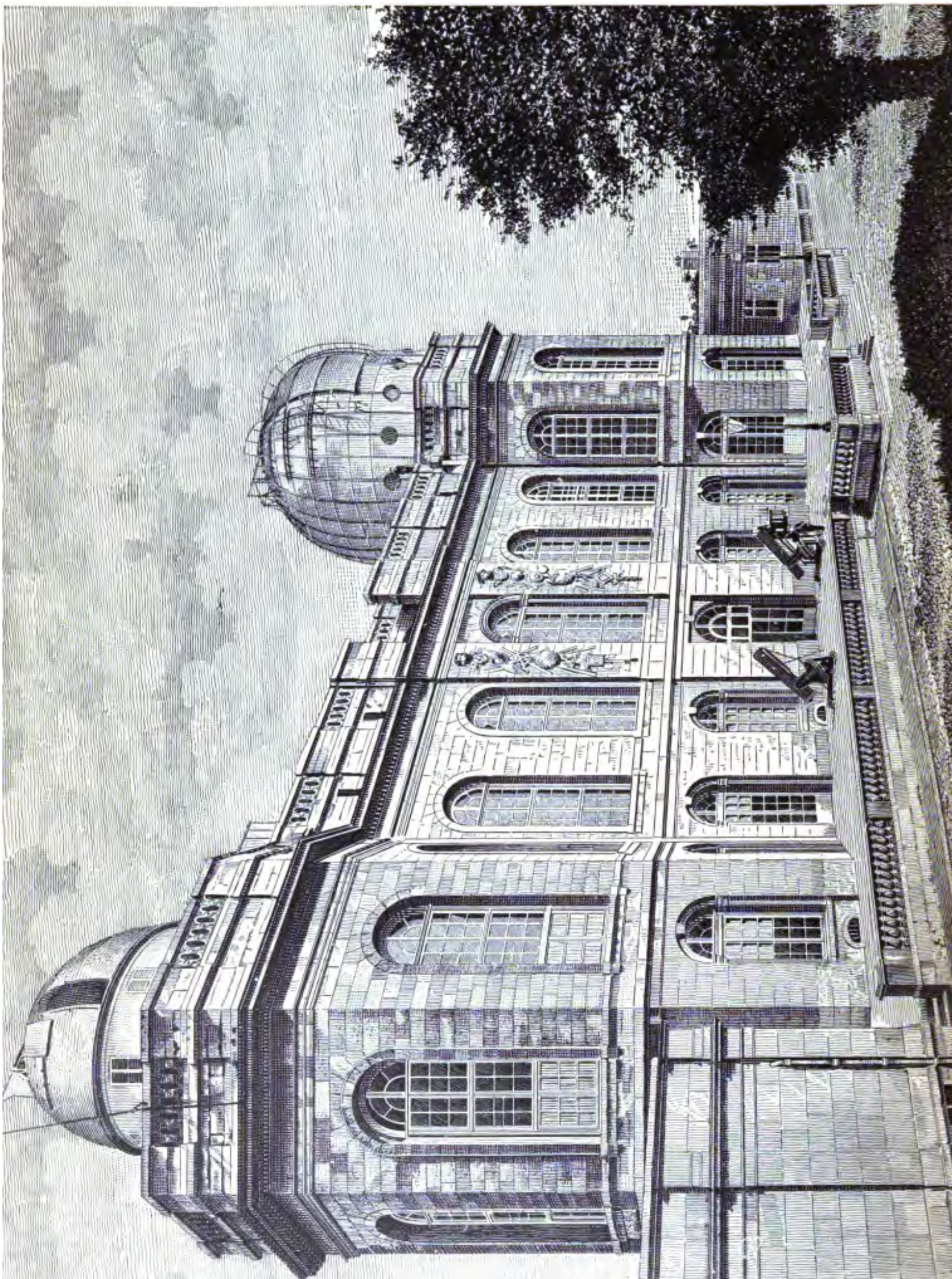
Some of this should be devoted to the publication of the annual volumes of the observatory which should be gratuitously circulated among observatories, libraries, scientific societies, and among eminent astronomers. The prompt publication of important researches increases their value tenfold.

In return for these publications the new observatory would receive those of all the principal observatories and scientific societies of the world.

The above are a few of the considerations which seem best fitted to be observed in the founding of the new observatory, and in giving them, I have abstained from questions of detail, except where the detail was needed to illustrate a principle. The view taken of the use of the new observatory is not purely an astronomical one, nor yet a purely physical one, but astronomical science generally, it is believed, will be best served by following some such plan as the one here sketched out.

Respectfully submitted, EDWARD S. HOLDEN.

* Foot-note added 1892. I am still of the opinion that this estimate is large enough, *provided* the work when once begun had been pushed to completion at once. The delay has thus been very costly. On the other hand the buildings and instruments are far better constructed than they otherwise would have been.



NOTICES FROM THE LICK OBSERVATORY.

Prepared by Members of the Staff.

The National Observatory of Paris.*

The accompanying cuts are copied from Lieut. Winterhalter's Report on European Observatories, by the kind permission of the Superintendent of the U. S. Naval Observatory (*See* Publ. A. S. P., vol. iii, page 40). The very short description here given is condensed from that of Lieut. Winterhalter and from other sources. The history and work of this celebrated observatory are so well known that no long account is necessary, but it will be of especial interest to all, to see the views of the building in which the most famous astronomers of France have labored. The mere list of its Directors is a reminder of the brilliant place of France in the domains of practical and theoretical astronomy and astronomical physics. The Directors have been J. D. Cassini (1669–1712), J. J. Cassini (1712–56), C. F. Cassini de Thury (1756–84), J. D. Cassini, Comte de Thury (1784–93), Lalande (1795– ?), Méchain (1801), Alexis Bouvard (1804), Arago (1811–53), Le Verrier (1854–70), Delaunay (1870–73), Le Verrier (1873–77), Mouchez (1877–).

The Observatory was built by Perrault, the famous architect of Louis XIV, about 1667, and is therefore one of the oldest as well as one of the most celebrated in Europe.

It has always been intimately connected with the French Academy of Sciences and its earlier observations were printed in the *Mémoires* of that institution. Its work in the last half of the present century is published in a magnificent series of some seventy quarto volumes, as well as in the *Bulletin Astronomique*,

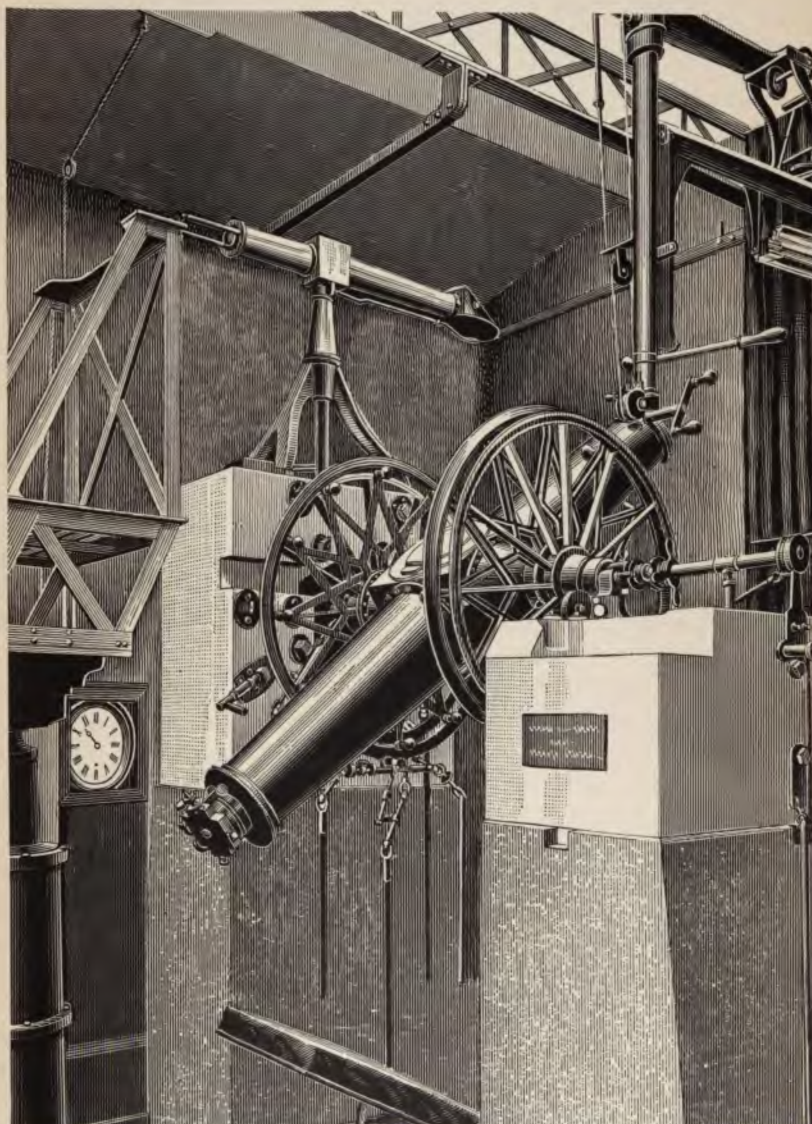
* Admiral E. Mouchez, Director.

a monthly journal of the very highest class. The principal instruments are a 29-inch, 15-inch, 12-inch, two 9½-inch refractors, two meridian circles and other meridian instruments and very many minor instruments.

The photographic refractor of 13 inches aperture, which has been taken as the model for all the instruments to be used in making the International Photographic Charts of the whole heavens, was made there by the MM. HENRY, who are connected with the observatory. The headquarters of this International undertaking are also at the Paris Observatory, and Admiral MOUCHEZ is the President of the Permanent Committee of the Congress.

The accompanying cut represents the Meridian Circle which was presented to the observatory in 1878 by M. BISCHOFFSHEIM (founder of the great observatory of Nice), and is especially interesting as showing the designs adopted by its distinguished constructor, M. EICHENS. The instrument is about of the same size as the REPSOLD Meridian-Circle of the Lick Observatory, from which it differs, however, in many respects.

A list of the principal instruments would be incomplete without a mention of the *equatorial coudé*, a new form of mounting invented by M. LOEWY, in which the eye-piece of the telescope (and therefore the observer) remains always in one place, while the image of the star under examination is brought to this eye-piece by reflections from two plane mirrors. The ingenious and important inventions of M. LOEWY for determining the principal constants of astronomy—refraction, aberration, flexure, etc.—can only be mentioned here. In fact it is impossible in this place to give any account of the work of the observatory, and it can only be said that it employs a very large number of astronomers and computers who are organized into various departments, with separate chiefs. The principal departments are—that of meridian observations (which has just completed the re-observation of all the stars of LALANDE'S catalogue, some 50,000 in number)—that of equatorial observations—of astronomical photography—of the time-service—of calculations—of the library and museum—and (until lately) of a school of practical astronomy. The museum is a collection of great interest and of historical importance and contains authentic portraits of the great astronomers as well as some of the instruments which have had a great history—like the sextant used by LACAILLE at the Cape of Good Hope



PARIS MERIDIAN-CIRCLE.

to construct his catalogue of southern stars (1750), the mural-quadrant of LALANDE (1774–1834),* etc., etc.

It is not the object of this note to do more than to give the briefest description of the observatory at Paris, which has had so brilliant a history. For a fuller account of its work reference is made to the *Astronomie Pratique* of the AUDRÉ and RAYET and to the Annual Reports of the Director, Admiral MOUCHEZ.

E. S. H.

TOTAL SOLAR ECLIPSE OF APRIL, 1893. LICK OBSERVATORY EXPEDITION TO CHILE.

The line of totality of the solar eclipse of April, 1893, passes across South America from Chile to Brazil and cuts the African coast in Senegambia. It is probable that parties from the United States and from Europe will establish stations on both sides of the Atlantic Ocean in Brazil and in Africa. The Harvard College Observatory has a station in Peru and will probably observe the eclipse somewhere in South America. At the suggestion of Professor SCHAEBERLE plans were made for sending an observer from the Lick Observatory to the west coast of Chile, and the necessary expenses of such an observer have been provided for by the generous gift of a friend of the observatory. The expedition from the Lick Observatory will be entirely photographic and its object will be to secure pictures of the inner and outer corona on the general plan which was so successful at the eclipses of January and of December, 1889.

The instruments to be employed will be, the 6½-inch equatorial, the 5-inch (40 foot focus) photo-heliograph objective, and a DALLMEYER portrait lens. Professor SCHAEBERLE may have the volunteer assistance of Mr. GALE, an amateur of Paddington, N. S. W.

E. S. H.

EXHIBIT OF THE LICK OBSERVATORY AT THE WORLD'S FAIR IN CHICAGO.

The World's Fair Commission of Santa Clara County, California, has set apart the sum of $300 to aid the Lick Observatory in preparing an exhibit for the World's Fair in 1893. The observatory proposes to send a large model of the Summit of Mount Hamilton, showing the principal building to scale; as well as to

* *See* LALANDE'S *Astronomie*, vol. ii.

display a large number of framed glass transparencies of astronomical photographs taken here together with similar transparencies of the buildings, instruments and apparatus. Messrs. WARNER & SWASEY will send a large drawing of the 36-inch equatorial on a scale of $\frac{1}{12}$. The Union Iron Works may also send a model of the great *Dome*. E. S. H.

IMPROVEMENTS OF THE MOUNT HAMILTON ROAD.

The Road Master of the Mount Hamilton District has agreed to place stout posts on the outside of the road at the most dangerous points and the Regents of the University will furnish stout wire-rope to string through the posts. In this way the road will be made safe to drive over at all times.

It has always been perfectly safe by day; but the present improvement will remove the risks which certainly have attended driving over the road by night, especially in stormy and dark weather. Fortunately no accident has occurred, so far, on the seven miles of mountain road. E. S. H.

POPULAR SCIENCE IN BERLIN.

The streets of Berlin are soon to be enriched by a large number of so-called "Urania pillars," of which it is proposed to set up in all 300. These pillars will be about 18 feet high, constructed of cast iron, and will each contain a clock, meteorological instruments, weather-charts, astronomical and geographical announcements, and also, as in the streets of Paris, a plan of the neighboring streets in enlarged form to enable strangers to find their way. The instruments are to be regulated from the observatory. —*Public Opinion*, April 8, 1892.

POMONA COLLEGE PRESENTED WITH A NEW TELESCOPE.

POMONA, April 26.

The students and friends of the Pomona Congregational College are happy at the news of the purchase of an $8000 telescope for that institution by some unknown lady in Ventura county. The purchase was make some weeks ago, and the instrument will soon be formally presented to the college. The telescope will be the largest of the kind in Southern California.

—S. F. *Chronicle*, April 27, 1892.

Scientific Visitors to the Lick Observatory.

Dr. D. Kirkwood, the Dean of American astronomers, who is now in his 78th year, paid a short visit to the Lick Observatory in May, after the completion of his course of astronomical lectures at the Stanford University at Palo Alto.

A Glimpse of Kepler.

In the year 1623 Duke Ferdinand y Gonzaga wishing to give more renown to his little University of Mantua determined to seek for the most celebrated man of Austria to become the Professor of Mathematics. Accordingly he addressed a note to Zucconi, his minister-resident at Vienna, to instruct him to find the savant who was wanted. The reply of Zucconi is interesting as throwing a light on the state of learning in Vienna at that time and especially as giving us a glimpse of the great Kepler. Zucconi answered the Duke that he would do his best to find the mathematician in question, but that the Duke must recollect that such matters were not of the least interest to the Viennese: "*in questa città si attende a ogni altra cosa*"*!* And, moreover, the only man he could think of was one Kepler, of Linz, who was reputed to be the first mathematician of Germany; but as in the first place, he was a heretic, and as in the second, he was disposed to remain comfortably at home—"*per star comodissimamente in casa sua*"—the arrangement was utterly impracticable. —*Geschichte der Weiner Journalistik*, von E. V. Zeuker, noticed in *Revue des Deux Mondes*, vol. 110, p. 699.

Photographic Telescope for the University of Mississippi.

Sir Howard Grubb, F. R. S., is engaged in making a pair of large equatorials for the University of Mississippi, which will be mounted side by side. The visual telescope will have an aperture of 15 inches and the photographic an aperture of 9 inches.

E. S. H.

The Number of Stars shown on some Stellar Photographs [by Dr. Max Wolf, of Heidelberg].

In the *Astronomische Nachrichten*, no. 3091, Dr. Wolf gives some interesting statistics of counts which he has made on three

negatives of the region near *Alpha Cygni.* The negatives were made with a 5-inch "Kranz-Aplanat" photographic lens and were exposed:—

No. 1 . . 1 hour; No. 2 . . 3 hours; No. 3 . . $13\frac{1}{10}$ hours.

By accurate counting in certain areas and by estimation from these counts, Dr. WOLF finds the number of stars (approximately) per square degree as follows:—

No. 1 . . 467; No. 2 . . 973; No. 3 . . 1770;

and the whole number of stars shown on the 1000 square degrees covered by the plates:—

No. 1 . . 52,000; No. 2 . . 108,000; No. 3 . . 197,000.

The maps of ARGELANDER'S *Durchmusterung* show in this 1000 square degrees about 3500 stars. Dr. WOLF concludes that his longest exposed plate shows 15th magnitude stars. Plates with 1 hour's exposure show stars of 11.5 visual magnitude; with 2 hours' exposure, 13.5 magnitude, and with 6 hours' exposure, 14 magnitude. E. S. H.

RESIGNATION OF MR. S. W. BURNHAM AS ASTRONOMER OF THE LICK OBSERVATORY.

Mr. BURNHAM has resigned his position as Astronomer in the Lick Observatory and has accepted that of Clerk of the United States District and Circuit Courts at Chicago—a very honorable and a very lucrative appointment. Mr. BURNHAM'S resignation was presented to the Regents of the University at their meeting of June 14 and the following resolution was adopted by them.

"*Resolved*, That in accepting the resignation of Professor BURNHAM the Regents desire to express their high appreciation of his astronomical work at the Lick Observatory and their regret at his leaving, as his invaluable services will not only be lost to the Lick Observatory, but as we understand, to astronomical science."

Mr. BURNHAM leaves behind him a very large number of observations of double stars all prepared for the press which will appear as Volume II of the (quarto) Publications of the Lick Observatory. E. S. H.

Minutes of the Meeting of the Board of Directors held at the Lick Observatory June 11, 1892.

President Schaeberle took the chair and a quorum was present.

The minutes of the last meeting were approved.

The 18 members following were elected.

List of Members Elected June 11, 1892.

Mrs. H. R. Arndt	San Diego, Cal.
William W. Austin	Vineland, Cumberland Co., New Jersey.
W. H. Devine	Nagasaki, Japan.
W. S. Eichelberger	Wesleyan University, Middletown, Conn.
Professor R. Lee Hamon	Hyannis, Grant Co., Nebraska.
Daniel Hanlon	1627 Jackson Street, S. F., Cal.
Mrs. Phebe Hearst	Care of W. R. Hearst, "Examiner," S. F., Cal.
Charles W. Holden	30 Congress Street, Boston, Mass.
C. G. Hubbard	San José, Cal.
Donald King	8 Church Lane, Strand, London, England.
Frank McClean, M. A., F. R. A. S.	Rusthall House, Tunbridge Wells, England.
F. Martens	College Point, Queen's Co., New York.
J. Messer	Care of Carl Ricker, Nevsky Prospect, No. 14, St. Petersburg, Russia.
Judge F. W. Miner	Providence, R. I.
James L. Park	Braddock, Pa.
T. J. J. See	Zimmer Str. 97, Berlin, Germany.
W. T. Sulzer	Louisville, Ky.
Professor L. Weinek	Imperial Observatory, Prague, Austro-Hungary.

The Treasurer presented his report which was received and filed.

On motion it was—

Resolved, that the Committee on Publication is authorized to print a

limited number of suitable advertisements on inside fly leaves at the end of each number of the *Publications* at the following rates, viz.:

One page, for one year	$40
One half page, for one year	20
One quarter page, for one year	10

(Reasonable changes will be allowed in the above from time to time.)

One page, for one insertion	$10
One half page, for one insertion	6
One quarter page, for one insertion	5

Shorter notices by agreement.

The payments for such advertisements must invariably be in advance.

Mr. PIERSON, of the Committee on Observatory in San Francisco, reported that the Park Commissioners had kindly granted a site in Golden Gate Park for the proposed observatory.

The following resolution was moved and seconded and postponed for further consideration:—

Resolved, That the By-Laws (Art. II) be amended by abolishing the status of Honorary and of Corresponding Members and making the necessary verbal changes. (See *Publ.* A. S. P., Vol. III, page 194.)

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD AT THE LICK OBSERVATORY, JUNE 11, 1892.

President SCHAEBERLE presided.

The minutes of the last meeting as printed in the *Publications*, were approved.

A list of presents was read by the Secretary, and the thanks of the Society voted to the givers.

Special attention was called to the beautiful album of engravings of the buildings and instruments of the Nice Observatory, presented by Mr. BISCHOFFSHEIM, the founder of the Observatory, and to the very rare medal of the Great Comet of 1680 referred to in *Publ.* A. S. P., Vol. II, page 124, presented by Professor HOLDEN.

The Secretary read the names of members duly elected at the meeting of the Directors.

The following programme was presented:

1. The Lunar Eclipse of January, 1888, by Professor WEINEK, of Prague.
2. The Proper Motions of Stars with different Spectra, by W. H. S. MONCK, of Dublin.
3. The McCORMICK Observatory, by H. A. SAYRE, of the University of Virginia.

4. A Trial of FOUCAULT's Pendulum Experiment, by TORVALD KÖHL, of Denmark.
5. Notice regarding the Astronomical Exhibit at the World's Fair, by GEO. E. HALE, of Chicago.
6. Verbal Accounts, by Professors SCHAEBERLE and CAMPBELL, of Observations of the Spectrum and Magnitude of the New Star of 1892; of Photographic Observations of the Great Sun Spot of February, 1892; and of Observations of the Spectrum of SWIFT's Comet. Illustrated by photographs made at the Lick Observatory.

Recent enlarged photographs of *Venus* and of *Saturn* made with the 36-inch equatorial and an enlarging lens by J. A. BRASHEAR were exhibited to the members, as well as similar photographs (by Professor SCHAEBERLE) of the region near the New Star in *Auriga;* photographs and drawings (by Professor CAMPBELL) of the spectrum of the New Star and of SWIFT's Comet; and some very successful photographs of stellar spectra taken in the 2d and 4th orders of a ROWLAND grating of 14,000 lines; etc., etc.

Adjourned.

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E. J. MOLERA (850 Van Ness Avenue, S. F.), ...
FRANK SOULÉ (Students' Observatory, Berkeley), ... *Vice-Presidents*
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F. R. ZIEL (410 California Street, S. F.), ... *Secretary and Treasurer*

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OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Messrs. DOUGLASS (Chairman), EWELL, HALE (Secretary), PIKE, THWING.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. IV. SAN FRANCISCO, CALIFORNIA, SEPTEMBER 3, 1892. NO. 25.

THE PARTIAL ECLIPSE OF THE MOON OF MAY 11, 1892.

By A. STANLEY WILLIAMS, F. R. A. S.

A cloudless sky enabled this eclipse to be observed with great satisfaction, though owing to the low altitude of the moon the seeing was confused and unsteady in the telescope. But regarded from the point of view of the naked-eye observer this low altitude was a decided advantage, as the progress of the phenomenon could be watched without discomfort. The eclipse on the whole was rather a dark one, though with the 6½-inch CALVER reflector used, and also in the 1½-inch finder, the principal features were readily traceable. About the time of greatest eclipse the part of the moon most deeply immersed in the shadow was of a rosy tint, not very deep; and from thence it faded away gradually to a bluish-greenish tint near the edge of the shadow. The general appearance about this time, subject to slight differences in the tints, closely resembled Professor WEINEK'S very beautiful colored drawing of the eclipse of January 28, 1888, in the *Publications* A. S. P., No. 23, but the eclipse portion was darker and not so deeply colored.

The principal work during the eclipse consisted in recording the times when the shadow outline reached and departed from different craters and other features. For this purpose a KELLNER eye-piece magnifying 58 times was used on the 6½-inch reflector. In making the observations the eye was allowed to run along the shadow outline, and the time when this outline appeared to cut centrally across the object observed, was the time noted. It would be difficult otherwise to obtain uniform results, since a conspicuous bright or dark object can be seen farther within the shadow outline than a less prominent one.

There has recently been some discussion as to the degree of accuracy with which observations of this kind can be made. The experience derived from the present eclipse shows, as might be expected, that a great deal depends upon the object observed. The most suitable appear to be small bright objects, such as Censorinus, and with these the times can be easily noted to a tenth of a minute. Large regular formations can also generally be well observed. In most cases, however, it is difficult to be sure of the time within a minute. It would be useful to carefully study a photograph of the full moon when contemplating observations of this kind so as to become well acquainted with the most suitable objects and to select those the positions of which have been well determined. The following is a list of the observations made during the late eclipse:—

Immersions.	G. M. T. h. m.
Copernicus, center	9 32.1
Plato I, border	9 32.1
Plato II, border	9 33.6
Manilius, center	9 49.1
Menelaus, center	9 52.6
Endymion, center	9 53.1
Lemonnier A	9 54.6
Titatus, center	9 57.1
Dionysius	9 58.6
Cleomedes A	10 4.8
Censorinus	10 7.4
Proclus	10 7.4
Tycho, interior N. E. wall	10 8.1
Tycho, center	10 9.8
Taruntius, center	10 11.8
Firmicus, center	10 17.1
Goclenius, center	10 18.8

Emersions.	
Tycho, outer edge of N. W. wall	11 27.1
Grimaldi, S. corner of dark interior	11 27.6
Grimaldi, middle of dark floor	11 29.3
Grimaldi, N. corner of dark interior	11 30.3
Gassendi, center	11 33.1
Pitatus, center	11 33.6

	G. M. T. h. m.
Pitatus, N. W. border	11 35.1
Munosius	11 37.6
Aristarchus	11 50.1
Bessarion E.	11 52.1
Copernicus, center	11 56.1
Copernicus, outer edge of N. W. wall	11 57.1
Euler	11 58.1
Pytheas	12 0.3
Fracastorius, N. W. border	12 2.4
Sinus Iridum, bisected	12 5.1
Timocharis	12 6.1
Cape Laplace	12 8.4
Dionysius	12 11.1
Plato, E. border	12 13.1
Plato, W. border	12 16.0
Menelaus	12 16.8
Posidonius, N. W. wall	12 28.0
Proclus	12 29.9
Endymion	12 34.3

BRIGHTON, June 22, 1892.

THE EFFECT OF PARALLAX ON THE PHENOMENA OF THE SATELLITES OF *MARS*.

BY W. J. HUSSEY.*

In treating of the phenomena of the satellites of *Mars* as seen from the surface of the planet, it has been customary for popular writers to disregard parallax and in consequence some of their statements are considerably in error. Some of these errors have appeared in well-known text-books and especially on this account it is desirable to call attention to this subject.

For a popular statement it is sufficient to use approximate data and calculations. Refraction due to the atmosphere of *Mars* may be neglected. Not enough is known of the constitution of the atmosphere of *Mars* to enable the amount of refraction due to it to be even roughly estimated. But it is doubtless small in comparison with the other quantities which we are considering

* Assistant Professor of Astronomy in the Stanford University.

and, although its tendency is to counteract the effect of parallax, it may be neglected without much error. *Mars* is nearly spherical, its satellites move in ellipses differing but little from circles and in planes very nearly coincident with the plane of the planet's equator. Hence, for the present purpose, it may be assumed that *Mars* is spherical and 4230 miles in diameter, that the satellites move in circular orbits in the plane of the planet's equator, that *Phobos* is 5850 miles from the center of the planet and *Deimos* 14,650 miles.

As seen from the surface of the planet and from its center, the satellites will in general appear in somewhat different directions. This difference of direction is the parallax of the satellite, and its value is greatest, for a given distance of the satellite from the center of the planet, when the satellite is in the horizon as seen from surface. The above quantities give a horizontal parallax of 21°.2 for *Phobos* and 8°.3 for *Deimos*. Neither of the satellites can be seen at or near the poles of the planet. *Phobos* never appears above the horizon of places having latitudes higher than 68°.8. For *Deimos* the limit is 81°.7.

Mars rotates in $24^h\ 37^m\ 23^s$, its satellites revolve in $7^h\ 39^m\ 14^s$ and $30^h\ 17^m\ 54^s$. Their motions are all from west to east. Their hourly rates of movement are 14°.88 for *Mars*, 47°.04 for *Phobos* and 11°.88 for *Deimos*. Since *Phobos* revolves more rapidly than *Mars* rotates, it would to an observer on *Mars*, rise in the west and passing quickly across the sky, set in the east. *Deimos*, like all the other heavenly bodies, rises in the east and sets in the west. The interval from one rising to the next, or from one setting to the next, is found by dividing 360 by the difference of the hourly rates of *Mars* and its satellites. This gives for *Phobos* about 11 hours and for *Deimos* about 66 hours. The intervals from rising to setting are considerably less than half of these. For instead of remaining above the horizon during half a revolution about the center of the planet, or 180°, they remain above it less than this by twice the horizontal parallax. This for *Phobos* is 137°.6 and for *Deimos* 163°.4 and the times required to describe these arcs are about $4^h.3$ and $59^h.6$. These are respectively the intervals which *Phobos* and *Deimos* remain above the horizon of a place on *Mars*' surface.

The diameter of the shadow of *Mars* at the distance of *Phobos* is about 4195 miles and at the distance of *Deimos* 4140 miles. These values are variable since the distance from *Mars* to the *Sun*

is variable, their variations being some 5 and 10 miles respectively either way. These variations are slight and have very little influence on the values of the quantities we are considering.

The satellites of *Mars* are frequently eclipsed but not invariably when in the position of full moon. The inclinations of the planes of their orbits to the plane of the planet's orbit, are so great that during certain periods they regularly pass above or below the shadow and are not eclipsed. This is the case when the satellites are far from their nodes at the times of full moon. Otherwise they are eclipsed at every revolution. Thus *Phobos* is not eclipsed if more than about 58° from either of its nodes, nor *Deimos* more than about 19°. On the average *Phobos* is eclipsed about two out of every three times that it is in the position of full moon and *Deimos* about two out of every nine times.

The eclipses vary in length, being longest when the satellite is at one of its nodes when in the position of full noon, for it then passes centrally through the shadow of the planet. The maximum duration of an eclipse of *Phobos* is about 53 minutes, for *Deimos* it is about 84 minutes.

During a night on *Mars* an observer on that planet may at times have the opportunity of observing two total eclipses of *Phobos*, one in the evening and the other the next morning. For such an opportunity to occur, the planet must be near one of its equinoxes and *Phobos* must rise at or very nearly the setting of the sun. Suppose the planet at one of its equinoxes and *Phobos* to rise as the sun goes down. This will be at six o'clock in the evening on *Mars*. About 3.4 terrestrial hours later, or a little before half-past nine, the sun will be about 50° below the horizon and *Phobos* 50° east of the meridian. The eclipse will then be at its middle, the total phase having begun some 26 or 27 minutes earlier. In as many minutes more, the total phase will end, and somewhat more than half an hour after the end of the eclipse *Phobos* will set in the east. It will rise again very soon after five o'clock the next morning. But it will then be invisible, being at the time totally eclipsed. This eclipse will have ended more than half an hour before the rising of the sun, and at the end of the total phase *Phobos* will be 15° or more above the western horizon.

NOTES OF A PRELIMINARY EXAMINATION OF PHOTOGRAPHS OF *JUPITER* TAKEN AT THE LICK OBSERVATORY IN 1891.

By A. Stanley Williams, F. R. A. S.

The Royal Astronomical Society has lately been presented with an extensive collection of original negatives of *Jupiter* taken at the Lick Observatory in 1891. The notes which follow are the results of a preliminary examination of these negatives and of a series of positive copies on glass, which, through the courtesy of Professor Holden, the writer was enabled to make of this magnificent collection. Astronomers on this side of the Atlantic should be greatly indebted to the authorities of the Lick Observatory for thus placing at their disposal such an extensive and valuable series of original photographs. The most perfect collection is, naturally, still preserved at the Lick Observatory itself, but in presenting as complete a set of duplicate negatives as possible to a suitable central station, an example is given worthy of being extensively followed. Photographs, however valuable in themselves, are of little use unless they are properly examined and studied, and the resources of few observatories are adequate to the proper discussion of the constantly accumulating results which such observatory is capable of turning out.

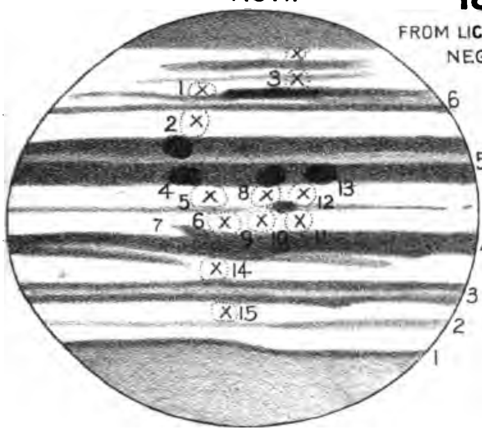
The present photographs were taken with the great refractor of the Lick Observatory, all the exposures having been made by Messrs. E. S. Holden and W. W. Campbell, and the plates having been all developed by the last named. The photographs were enlarged directly in the telescope rather more than eight times, the image of *Jupiter* on the plates measuring nearly an inch in diameter when the planet was near opposition. For further information as to the method of working, etc., reference should be made to a recent paper by Messrs. Holden and Campbell in the *Monthly Notices*, Vol. LII, page 499. It should be mentioned here, however, that one of the greatest obstacles to securing the finest results appears to lie in the presence of wind, since, to quote from the paper above mentioned, "the negatives are affected by the wind blowing on the instrument (and by other accidental disturbances) as if they were taken in the principal focus of a telescope 400 feet long."

JUPITER.

1891.

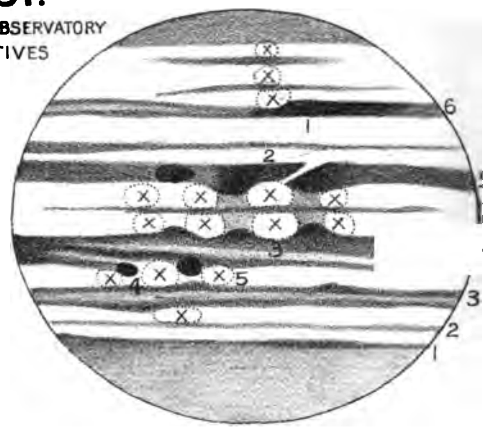
FROM LICK OBSERVATORY NEGATIVES

FIG. 1.



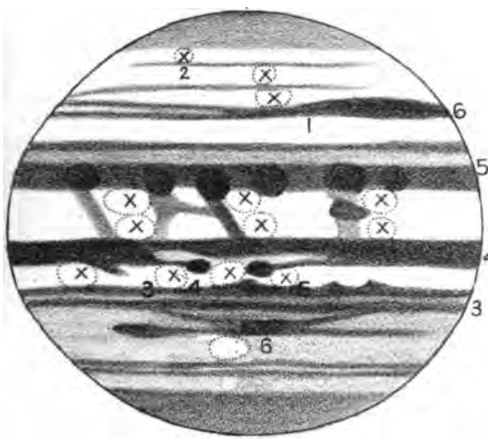
λ I. = 255°; II. = 153°.

FIG. 2.



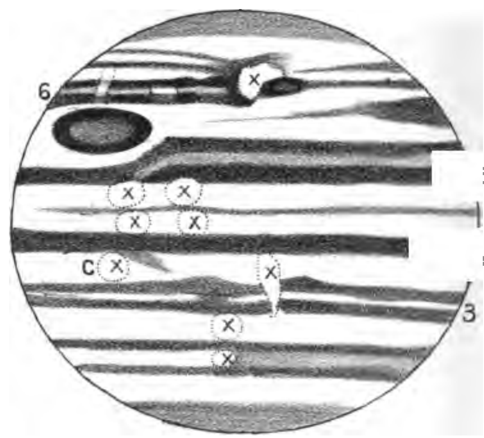
λ I. = 28°; II. = 278°.

FIG. 3.



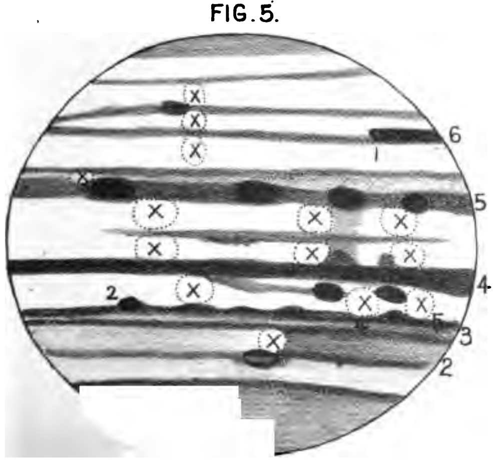
λ I. = 354°; II. = 253°.

FIG. 4.



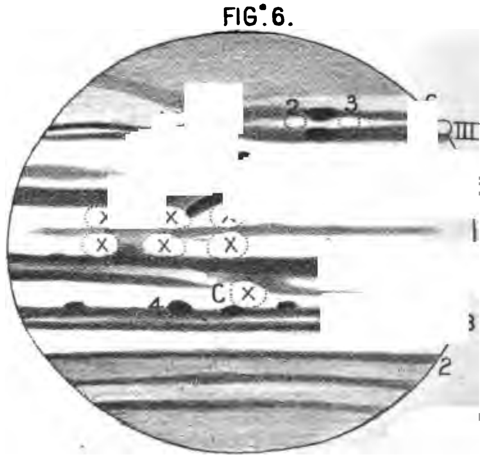
λ I. = 150°; II. = 42°.

FIG. 5.



[illegible]

FIG. 6.



[illegible]

The present notes are the result of a preliminary examination of the photographs. It is the writer's intention to eventually subject them to a much closer scrutiny, and to make an extensive series of measures of the positions of the different spots and belts. But the present notes will, it is conceived, serve to form a comprehensive index to these photographic records, which will be useful and available to all those who make a study of the planet; besides giving some idea of the excellence of the photographs, and of the rich amount of valuable information preserved in them. The figures which accompany this paper must not be considered in anyway as *copies* of the original photographs, or as giving a good idea of them. They have no pretensions to emulate Professor WEINEK'S beautiful drawings of the Lick lunar photographs, and they must be considered merely as diagrams or index maps to the originals. But every detail shown is present in the photographs, and with a few exceptions in a measurable form, together with many others not given.

The approximate zenographical longitudes of the central meridian of the planet's disc are given for each plate according to two systems employed by Mr. MARTH in his "Ephemeris for Physical Observations of *Jupiter*" in the *Monthly Notices*. System I relates to the markings in the equatorial zone and on the S. equatorial belt: System II serves for the remaining regions of the planet. It should be mentioned, however, that the dark spots on the south edge of belt 3 moved with exceptional velocity last year, so that their motion did not conform, even approximately, with either system of longitude. The times given are Pacific standard times. The chief belts are numbered uniformly in each figure on the outside of the disc: 3 is the double N. temperate belt; 4, the N. equatorial belt; 5, the double S. equatorial belt; 6, the double S. temperate belt. Lighter spots are indicated by a cross with a dotted outline.

In comparing these results with others, it should be recollected that the photographic image of the planet is not quite the same as the visual one. Red markings for instance, appear relatively darker on the photographs than they do in the telescope. The great red spot is thus more conspicuous in the photographs relative to other markings than it ever appeared to the writer at the same time with a 6½-inch reflector. The dark belts also usually appear narrower visually than they do photographically, probably because of the effects of irradiation produced by the adjacent

bright zones being greater in the former case. The phase-darkening of the disc when the planet is near quadrature is also more evident in the photographs than in the telescope.

PLATE I. 1891, Aug. 25, 12^h 28^m long. of C. M. I = 255°; II = 153°. See fig. 1. There are four images of the planet on the plate, which is a good one. The most striking feature shown is the remarkable short red streak in the southern hemisphere which has been termed by Mr. BARNARD "the new red spot." The great intensity or depth of tone of this streak comes out very strikingly. It is much the darkest marking on the disc. The photographs reveal several interesting details in connection with it. South of the preceding end of the streak is a small bright spot, and another fainter one lies opposite in the bright zone between belts 5 and 6. They also reveal a further peculiar and very important detail. In a recent valuable paper Dr. TERBY, of Louvain, has given an interesting account of his observations of *Jupiter* in 1891,* and he there expresses the opinion that the "new red spot" cannot be considered as constituting a more obscure portion of one of the southern belts of the disc, but that on the contrary it had appeared isolated, and situated between two belts. This view, however, is contrary to the evidence afforded by the Lick photographs. In these the S. temperate belt (6) appears *distinctly double.* One component band of this double belt *is in the same parallel with the new red spot,* the other and more conspicuous one lies north of it. Hence it would appear that Dr. TERBY whilst seeing clearly the northernmost component band of this double belt, failed to distinguish the southernmost band lying in the same parallel with the new red spot. It is a new proof of the value of these photographic records when we find that they appear able to extend and even correct the observations and inferences of so practised an observer. It may be mentioned that the duplicity of belt 6 is apparent in all four images, so that there is no doubt of its existence.

In the equatorial regions of the planet various important details appear. Particularly noteworthy are, the double aspect of the great south equatorial belt, and sundry dark streaks on the N. side of the N. equatorial belt. These streaks are slightly inclined to the direction of the belts, and evidently form part of the remark-

* "Sur l'apparition de plusieurs nouvelles Taches Rouges dans l'hemisphere austral de *Jupiter* et sur la Structure de la Bande septentrionale 4 de cette Planète." *Bull. de l'Acad. roy. de Belgique*, t. XXII, No. 11, pp. 378-386.

able complex structure discovered by Dr. TERBY.* In the light equatorial zone several brighter spots are shown distinctly, arranged in pairs. In 1891 the dark N. temperate belt 3 was the seat of great disturbance. A great number of blackish spots appeared on the S. edge of this belt, and were remarkable for the extraordinary quickness of their motion, something like 280 miles an hour relative to closely adjacent markings. In the photographs belt 3 is distinctly double, and an inclined arrangement of the streaks is apparent, which appears to support the suspicions of Dr. TERBY and the writer, from visual observations, that the belt may have had a structure analogous to that discovered by the former in the N. equatorial belt.

PLATE II. Aug. 26, $11^h 46^m$ long. I $= 28°$; II $= 278°$. Fig. 2. The four images on this plate are also good, and show a large amount of interesting detail. The following points deserve special notice. (1) The long dark streak marked 1 on belt No. 6. Viewed through the telescope this dark streak was colored very deeply with red. The photographs show that belt 6 is double preceding the streak, which, according to visual observations, was itself double, and was clearly merely a remarkably intensified portion of the belt. (2) The S. equatorial belt 5. This is conspicuously double on the preceding part of the disc, but towards the east the southernmost component becomes gradually narrower and fainter, until it dwindles away almost to nothing. This peculiarity has existed for several years past, and has served as a convenient index by which to know that the advent of the great red spot on the disc may be expected. The northernmost band of the double belt shows many details. Perhaps the most interesting is the curious narrow light rift extending in a *sf.* direction through the belt from the brilliant equatorial spot marked 2. This light rift recalls the bright streamers described by Professor KEELER as appearing to be projected from the bright equatorial zone into the dark equatorial belts in 1889.†

(3) The equatorial zone is remarkable for the curious pairs of light spots, and above all for the two very prominent spots marked 2 and 3 in fig. 2. These are very conspicuous in the

* See *Astr. Nach.*, No. 2928. The projecting streamer mark 7, which evidently forms part of the same structure, is only shown distinctly in one of the four photographic images.

† See *Publications* A. S. P., Vol. II, p. 287. The streamers in question form a portion of the complex structure of Dr. TERBY above referred to. There are a number of important points still requiring to be solved in connection with the true structure of the belts.

photographs, where they shine out almost as if they were luminous. They have also been extensively observed visually, both in the last apparition of 1891 and in the preceding one of 1890, and they are still visible. Their rate of rotation has conformed very closely in this period with that adopted by Mr. MARTH as the basis of his ephemeris "System I," but their motion has not been perfectly uniform.

(4) The N. equatorial belt. Here there are many interesting details. Particularly noticeable is the curious system of rifts or streaks forming part of TERBY'S structure already alluded to. On the N. edge of the belt are two very dark spots, and in the bright zone on the north are two very bright luminous looking spots marked 4 and 5, and a third smaller and fainter one to the left. These markings formed a very characteristic feature of the planet last year. It is a little doubtful from the photographs, on a preliminary examination whether the bright spot 5 may not break into the rift on the S. of it. In any case, however, the photographs reveal more of the real structure of this belt than do most of the published sketches of the planet.

(5) The N. temperate belt 3 is again clearly double. Between the white spots 4 and 5 is a dark projection or spot, one of those remarkable for the rapidity of their motion; and on the right is a fainter object of the same kind.

PLATE III. Sept. 28, $10^h\ 33^m$ long. I = 158°; II = 156°. The night of Sept. 28 was a very windy one, and in consequence there is a great falling off in the quality of the photographs. Spots and other details are not indeed wanting, but the outlines are ill-defined, and present a washed-out appearance very different from the sharp clean aspect which they have in the photographs taken under favorable conditions. The chief points of interest are,—

(1) The "new red spot" numbered 3 in fig. 1. The *f.* end of this spot, which is of course very prominent, is nearly on the central meridian of the disc, the little bright spot at its *p.* end being just distinguishable. Belt 6 gives the impression of being double *f.* the spot rather strongly, and its southern edge is apparently continuous with the southern edge of the "new red spot," thus confirming the indications of plate I relative to this marking being merely a greatly intensified portion of the belt.

(2) The S. equatorial belt is double, and on the northernmost component are two large and rather conspicuous dark masses. In

the equatorial zone are some faint light spots and a faint dark streak connecting the two equatorial belts.

(3) The N. equatorial belt shows several spots and irregularities, but the image is not sharp enough to clearly decipher the structure. The N. temperate belt gives feebly the impression of being double.

PLATE IV. Sept. 28, $10^h\ 42^m$ long. I = 163°; II = 162°. Having been taken only about 9^m after plate III and under similar conditions, the descriptions relating to the last photograph apply with equal force to the present case. But a little distance eastward of the central meridian there appears to be a narrow bright rift cutting right through the N. equatorial belt nearly at right angles to the direction of the belts. Also there is a conspicuous dark spot on belt 3.

PLATE V. Sept. 28, $11^h\ 54^m$ long. I = 207°; II = 205°. The photographs are again comparatively poor owing to the windy night. The N. equatorial belt is greatly enlarged on the *f.* half of the disc, this enlarged portion being the part represented in fig. 2. The N. temperate belt 3, which is double, is pushed northwards on account of this increased thickness of the N. equatorial belt. The narrow light rift referred to in the description of the last plate as cutting through the N. equatorial belt is shown more clearly than before, and appears to be a very curious feature. It lies about half way from the C. M. to the *p.* limb. Its longitude is very approximately 175° (System II). The S. equatorial belt is double, the southernmost band being much narrower than the other. Belt 6 is also distinctly double.

PLATE VI. Oct. 11, $8^h\ 59^m$ long. I = 354°; II = 253°. Fig. 3. The longitude of the central meridian (System II) is not very dissimilar from that of fig. 2 (Aug. 26), so that it is interesting and instructive to compare the photographs made on the two dates, and to note the changes which have occurred in the interval of 46 days. In the region south of the S. equatorial belt but little change has occurred. It should be noted, however, that, owing to the westerly drift of markings here, the different objects, and in particular the long intensely dark streak marked 1, have all suffered a displacement relative to the bright and dark spots on the N. side of the N. equatorial belt. The equatorial markings have made very nearly a complete revolution of the planet relative to these latter spots, so that the two bright spots, 2 and 3 of fig. 2, are identical with the two easternmost equatorial spots of fig. 3,

where they are too far from the C. M. to show with best advantage. Similarly the two spots at the centre of the disc in fig. 3 are identical with the westernmost equatorial spots of fig. 2.

On the N. side of the N. equatorial belt we find also little alteration. The two bright spots marked 4 and 5 are very conspicuous in the photographs of Oct. 11, as they are on those of Aug. 26. Spot 4 is particularly prominent.* The spot marked 3 is also a very bright one. Being nearer the C. M. it is better seen than in the photographs of Aug. 26. It seems nearly to break through into the bright rift on the S. Some change has occurred, however, in the structure of the N. equatorial belt here. The rifts are not traceable to the same extent as on the photographs of Aug. 26, whilst the bright spot 4 is clearly in connection with the easternmost rift.

But it is in the N. temperate belt 3 and the region north of it that the most considerable changes have occurred. This portion of the planet is very obscure in the photographs of Oct. 11, and the details are not easily distinguishable clearly. Hence more careful study will probably render alterations necessary in some of the minor details shown in fig. 3. The spot marked 6 is rather conspicuous, however, and it would seem that the bright spot visible to the west of it is the same as the bright spot shown in fig. 2 just on the N. side of the double belt 3, and that it may have been forced into a more northern latitude by the extension of the dark material here. On the S. edge of the double belt 3 is a conspicuous dark spot on the central meridian with two fainter ones to the east of it.

PLATE VII. Oct. 11, $10^h\ 7^m$ long. I $= 35°$; II $= 294°$. In the interval of over an hour between the exposures the markings shown in fig. 3 have all made a great stride to the westward through the rotation of the planet. The long dark streak 1 is a long way past transit. Just south of its *f.* end is a small spot of remarkable brilliancy, a noticeable object. On the *f.* limb is the great red spot.

In the equatorial zone are a number of the usual light spots. The two numbered 2 and 3 in fig. 2 are now better seen, and the former penetrates deeply into the S. equatorial belt. The complicated portion of the N. equatorial belt depicted in figs. 2 and 3

* This spot was first observed by the writer as long ago as April 10, 1887, and it has ever since continued to be an object of exceptional brilliancy. For the observations of 1887 see *Zenographical Fragments*, I, p. 32, where the spot has been named L.

is now disappearing near the *p.* limb of the planet, and the remainder of the belt is comparatively monotonous.

On the south edge of the double belt 3 are no less than six of the curious dark projecting spots. The region northward is still very obscure, but the belts are more distinctly marked and appear to have been less disturbed.

PLATE VIII. Oct. 11, 11^h 6^m long. I = 71°; II = 330°. Owing to the rotation of the planet the great red spot is now wholly on the disc, whilst the long streak 1 of fig. 3 is on the preceding limb. The bright spot just S. of the *f.* end of the latter is very conspicuous. South and east of it can faintly be distinguished a dark shading which visually was one of the most curious objects which the writer recollects seeing on the planet. In the telescope it appeared of an oval shape and nearly as large as the great red spot, its color too being distinctly pale reddish. But the chief peculiarity consisted of an almost indescribable filmy, gauzy, wispy indefiniteness of aspect. The great red spot appears very dense in the photographs, but owing to wind having sprung up the outlines are not very sharp. Belt 6 is darker above the spot, with which it seems in contact, and is here distinctly double. In the equatorial zone are a conspicuous pair of bright spots, a little west of the central meridian, and other details; amongst them being a pair of dark streaks near the center of the disc, two dark spots on the S. equatorial belt, and two dark projections on the S. edge of the N. equatorial belt. Belt 3 is broad and dense, its duplicity being just distinguishable. On its S. edge are one or two spots.

PLATE IX. Oct. 12, 8^h 57^m long. I = 150°; II = 42°. Fig. 4. Although marked "windy" the plate is a very fine one, the images (three in number) being remarkably dense and showing much detail. In the positive copies the red spot and chief belts come out nearly black and almost opaque in some cases. The chief points of interest are,—

(1) The great red spot. This is distinctly annular, the interior being lighter, and the *p.* end appears blunter than the *f.* one, probably because it is more foreshortened. (2) Above the red spot, but separated from it by a clear interval, is belt No. 6, which is shown to be distinctly double. In the light rift of the belt are at least two brighter spots, one of which, just above the red spot, seems to extend faintly right across the double belt. Near the central meridian belt 6 is quite broken up and distorted almost

beyond recognition; the different fragments of it enclose a conspicuous brighter spot. (3) The equatorial belts. Few variations in the shape of definite spots are shown. The double character of the S. equatorial belt *f.* the red spot comes out well, however, as does also the deep hollow or bay opposite the latter. On the N. side of the N. equatorial belt is a brighter spot marked C in fig. 4. This spot is particularly notable on account of its remarkable longevity. It was first observed by Mr. DENNING, at Bristol, as long ago as Jan. 27, 1885; subsequently by Dr. TERBY, at Louvain, on March 19, 1885; and it has since been extensively observed at every successive apparition of *Jupiter* up to the present time.

(5) Belt No. 3. This appears very obscure and enormously swollen. In point of plainness it is very little inferior to the N. equatorial belt. A little east of the central meridian a curious light streak appears to cut right through the belt. The duplicity of the belt is just traceable, but it is not at all easy owing to the breadth of the component bands. The chief belts, rather curiously, all appear darker and broadened at the limbs, particularly at the *f.* limb of the planet.

PLATE X. Oct. 25, $8^h\,56^m$ long. I $=42°$; II $=195°$. Owing to the presence of wind the outlines of the belts are blurred and indefinite. Belt 6 is evidently double, and a little east of the central meridian are two dark spots on it, one on either component of the double belt, and nearly opposite each other. The N. equatorial belt becomes much enlarged near the *f.* limb.

PLATE XI. Oct. 25, $9^h\,39^m$ long. I $=68°$; II $=221°$. Fig. 5. There are three images on the plate, but as in two of them the features are very much blurred, owing to the presence of wind, most of the details shown in fig. 5 depend upon the examination of a single image, and hence it is difficult to eliminate the effects of spots and defects in the film. The chief points of interest are,—

(1) The long red spot 1 on the *f.* limb. (2) A curious row of three brighter spots west of the central meridian, the central spot being the plainest. There is an appearance as if the spots extended faintly across the two narrow dark belts, but it is not very decided. Just west of the bright spots is an obvious dark spot, which, according to Dr. TERBY, was red.

(3) The S. equatorial belt. This is curiously broken up into conspicuous dark cloudy patches, the portions of the belt between which are very feeble and apparently much encroached upon by

bright material. The southernmost component of the belt is very feeble and narrow.

(4) The N. equatorial belt. Compare this with figs. 2 and 3. The bright spots 4 and 5 are numbered alike in all three figures. In the present photograph the structure on the N. side of the belt is not very clear. The dark spots on either side of spot 4 are obvious, but the remaining dark parts are faint and indefinite, and there seems to have been a distinct fading away in the intensity of the dark material on the northern side of this belt.

(5) Belt 3. There are at least five dark spots on its southern edge. Two of these are very conspicuous, namely, the spot marked 2, and the one situated between spots 4 and 5.

(6) The dark spot on belt 2 is double, and seems to be formed chiefly by two overlapping ends of the belt where broken, but this is not quite clear. It may be mentioned here, that the two westernmost bright spots shown in the equatorial zone in fig. 5 are identical with spots 2 and 3 of fig. 2.

PLATE XII. Oct. 25, $11^h\ 17^m$ long. I = 128°; II = 280°. Although still windy, the photographs are very fair. The long red spot 1 of fig. 5 is now a little past transit, the bright spot at its *f.* end, referred to under Plate VII, being very conspicuous. The S. equatorial belt still continues very spotty and uneven. In the equatorial zone are also a number of spots and other details. Just past transit is a particularly obvious pair of bright spots. The complicated portion of the N. equatorial belt shown in fig. 5 lies near the *p.* limb, the bright spots 4 and 5 being still conspicuous, as are also the adjacent dark spots. The whole surface to the north of belt 3 is very obscure, but the belts here are less disturbed. Belt 3 itself is very broad and dark, its duplicity being just traceable.

PLATE XIII. Aug. 19, $13^h\ 51^m$ long. I = 78°; II = 20°. Fig. 6. Although last in order of consideration the present photograph is first in point of date, and is in every way a remarkably fine specimen, perhaps, indeed, the finest and most interesting photograph of *Jupiter* that has ever been obtained. The original negative is preserved at the Lick Observatory, but there is a positive copy on glass in the library of the R. A. S. Fig. 6 gives but a poor idea of the wealth of delicate details contained in this photograph. The following are some of the chief points of interest,—

(1) Belt No. 6 is very distinctly double, and *f.*, the central

meridian, is very broad. Above the red spot is a very brilliant white spot marked 1. Owing to its great brilliancy and its situation relative to the red spot this object was extensively observed last year, and it has been figured by Mr. DENNING in the *Observatory*, 1891, page 329. Its slow westerly drift relative to the red spot is well seen by a comparison of this sketch with fig. 6. Following it are two fainter spots numbered 2 and 3, situated in the rift of the double belt 6.

(2) The great red spot. This appears very distinctly annular, the interior being considerably lighter than the rest. The shadow of satellite III is projected on its *f.* end, the satellite itself being visible about half entered on the disc.

(3) The S. equatorial belt. Very remarkable, is an obvious tendency to the formation of short inclined streaks, the dark streak immediately *f.* the red spot being particularly evident. This peculiarity evidently has some relationship to a structure of the belt resembling that discovered by Dr. TERBY in the N. equatorial belt. It should be noted that these streaks are inclined in the opposite direction to those of the N. equatorial belt.

(4) The equatorial zone, which contains several rather plain bright spots. The faint dark belt in the middle is fairly plain.

(5) N. equatorial belt. On the N. side of this belt is the very remarkable bright spot C, referred to under Plate IX, the history of which dates back to January, 1885. It is very distinct in the photograph. From it a narrow bright rift extends into the N. equatorial belt, and can be traced almost up to the *p.* limb of the planet. It resembles the bright streamers observed by Professor KEELER in 1889, with the difference that instead of appearing projected from the equatorial zone into the belt, it appears as if projected from the bright extra-equatorial zone into the same belt. It evidently forms part of TERBY'S structure.

(6) Belt No. 3. The photograph shows this to be double with great distinctness. On the S. edge are six of the curious rapidly moving spots, and on its N. side a seventh dark spot.

It will be seen that fig. 6 shows twenty-four distinct spots, all of which are perfectly obvious in the photograph, where there are also many additional fainter ones and various other delicate details. The photograph evidently therefore compares favorably with the *average drawing* of *Jupiter* in point of quantity of detail, and is certainly immensely more accurate; though of course we can see visually much more minute details than can be photographed at present.

PHOTOGRAPHIC DISCOVERY OF A NEW CRATER ON THE MOON.

By Professor L. WEINEK, of Prague.*

On the first day of March of last year I made a thorough examination of an excellent photograph of the moon on glass, which was taken on August 27th, 1888 in the focus of the 36-inch giant telescope of the Lick Observatory at Mount Hamilton. I had constructed a suitable apparatus for this purpose, and subjected *Mare Nubium* (Sea of Clouds), which is situated in the southeast quadrant of the moon, to a careful comparison with the very best and most complete maps in existence. In the course of this investigation I noticed a small and distinct crater on the photograph, which was not shown on any of the maps. If we follow Section VIII of SCHMIDT'S large map, the diameter of which is two metres, the position of the crater will be: $\lambda = -9^{\circ}.0$ (longitude east); $\beta = -25^{\circ}.7$ (latitude south). As the photograph in question was taken shortly before last quarter, (moon's age = 20 days, with *Descartes* and *Julius Cæsar* on the terminator,) the small crater presents its west wall as illuminated, while the eastern interior lies in shadow. I estimate the size of this crater to be at least 1783 kilometres = 0.24 geographical miles, which would give it a diameter of one millimetre on SCHMIDT'S map. Now as this distinguished selenographer, whose maps of the moon show more detail than any others, presents this locality as perfectly level and having no craters of half its size in the immediate vicinity, it appears difficult to imagine that the recording of this new object was simply overlooked by him. Possibly the small elevation to the northeast represents SCHMIDT'S conception of this crater; but in this case it would become necessary to presume that considerable errors in position had been made in this part of Section VIII. On the other hand, under the same supposition, a crater (shown only on LOHRMANN'S map) situated a little to the west and south, but whose diameter would be 2.6 times too great, might be looked upon as being the object in question.

Although attempts were made to identify the new crater on other Lick Observatory plates (of which the Prague Observatory

* Translated for the Society by F. R. ZIEL, Esq.

possesses more than fifty—owing to the kindness of Professor E. S. HOLDEN) they were not successful in the beginning, and it was for this reason that the publication of the discovery of this crater was postponed.

It furthermore seemed desirable to wait until an optical verification, by an ocular observation at the telescope, could be obtained. All attempts made at Prague with this object in view have as yet been unsuccessful, owing to unfavorable weather at the times of last quarter of the moon.

Researches made in this direction by the expert observers, Messrs. E. S. HOLDEN, at Mount Hamilton, and T. G. ELGER, at Bedford, England, to whom I had furnished drawings of the new crater and vicinity,—enlarged twenty times,—showed no better results.

On the first day of July of last year I finally succeeded in obtaining, by other means, the desired proof of the existence of this crater, while I was engaged in making a thorough examination—under a magnification of 20, 30 and 40 diameters, of a negative of the moon, which was made on Sept. 22d, 1890 at $8^h\ 3^m$ Pacific standard time ($= 17^h\ 0^m.7$ Prague mean time), viz.: Sept. 23d at $5^h\ 0^m.7$ A. M., which Professor HOLDEN had sent me for the purpose of enabling me to make drawings of the numerous fine rills in the vicinity of a crater, which I had discovered photographically in *Sinus Medii* on May 22d, 1891. This plate was made shortly after first quarter and the shadows are on the opposite side to those on the plate of Aug. 27th, 1888. The new crater is also shown on this plate and can be seen without difficulty, the east wall being in bright light and the westerly interior showing a dark shading. Its position agrees accurately with the location given above. This plate also shows a distinct formation of rills, to the east of the new crater, at a distance of about half a geographical mile, extending from south to north in the shape of a small Greek *zeta* (the middle corner being flattened) which is at least five geographical miles long and about 713 metres, or more than 2000 feet, wide. This rill has also not as yet been seen by others; I have found it to be plainly visible on a plate taken at the Lick Observatory on November 3d, 1890, at $14^h\ 0^m$ P. s. t. (moon's age $21^d\ 5^h$) being illuminated from the opposite side and apparently extending in a northerly direction as far as *Birt*.

The new crater may be easily found with the aid of the following explanation. It is well known that in *Mare Nubium* to

the east of the ring plane *Thebit*, there is an almost perfectly straight mountain range, 14 miles long, which MAEDLER calls β and which, according to this prominent selenographer, has an average elevation of 157 toises, or 306 metres. MAEDLER compares the shape of this remarkable and surprising object to a cane, the upper end of which is ornamented by antlers; in small instruments it looks like a straight sword with a handle in the shape of a cross. To the east and near the centre of it is situated the deep ring plain *Birt* (MAEDLER = *Thebit* B), adjoining which on the southwest is a small crater. The diameter of *Birt* is nearly 2.5 geographical miles. Now, by starting from the center of this ring plain and proceeding in an exactly southerly direction, to a distance five times as great as its diameter, the new crater will be found. To the northeast of it, at a distance of five and nine geographical miles, respectively, there are two well known large craters of similar characteristics. It would naturally be of great value if a number of astronomers, who are provided with sufficiently powerful telescopes, would direct their attention to the optical verification of this crater, which was discovered by the aid of photography alone.

PRAGUE, July 3, 1892.

NOTE ON THE AUGUST METEORS OF 1892.

By Professor DANIEL KIRKWOOD.

The well known epoch of the August meteoric shower has just passed. The phenomena have been watched by the present writer for nearly half a century, and the failure of 1892 has been the most complete that has occurred in clear weather since the commencement of his observations. At Riverside this year shooting stars have not been more numerous from the 8th to the 11th of August than on ordinary nights. In fact not more than half a dozen were counted, though the evenings were quite clear on the 9th and 10th. Unless the experience elsewhere has been different, this fact must be regarded as indicating a notable gap in the cluster of August meteors. The writer has counted in former years from ten to a hundred meteors per hour. It will be interesting to watch next year to learn whether we have entered a wide chasm in the meteor ring, or whether the interruption is merely temporary.

RIVERSIDE, August 11.

A SUGGESTION TO UNIVERSITY INSTRUCTORS OF CLASSES IN ASTRONOMY.

By C. B. Hill.

In every class which is annually carried through the prescribed work in Practical and Theoretical Astronomy at our Colleges and Universities, an immense amount of laborious computation is undertaken by each student. The text-books contain problems for solution with each set of formulae, and consequently the eclipse of the sun which happened in March, 1858, and the transit of *Mercury*, May, 1832 (for example), are computed over and over again by hundreds of students with a persistence and energy worthy of a better cause.

My idea is that all this expenditure of time and energy might profitably be utilized, with equally valuable educational advantages, for the prediction of future events instead of the verification of past ones. This would serve greatly to interest and to assist the astronomical public, even if it should not materially aid the working observatories.

For instance, an occultation of the planet *Mars* by the moon will take place on the night of Sept. 3-4, 1892; it is possible that *Saturn* on November 14 and *Venus* the following day may present similar phenomena to our Pacific Coast vision; but few of the members of the A. S. P. could find the necessary time to work out the predictions, and ascertain the possibilities and particulars of these interesting phenomena. And while the observation of such events belong more to the old school of astronomy, and may not be considered of particular value at the present day, they certainly interest a very large circle of amateur workers who have, perhaps, neither the time nor the ability to make the predictions from almanac data. It is very distressing, not to say positively discouraging, for a business man to spend all one evening in a painful struggle with the formulae, only to find that sin ψ comes out greater than unity!

I am sure that the A. S. P. would be glad to publish in its journal the results of such predictions made by the University classes—there may be difficulties in the way which I do not fully appreciate, but the suggestion is offered for what it is worth.

THE PHYSICAL OBSERVATORY OF MEUDON (NEAR PARIS).

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

THE PHYSICAL OBSERVATORY OF MEUDON (NEAR PARIS).*

The accompanying cut is copied from Lieut. WINTERHALTER'S Report on European Observatories by the kind permission of the Superintendent of the U. S. Naval Observatory (*See* Publ. A. S. P., Vol. III, page 40). The note here given is condensed from the text of Lieut. WINTERHALTER'S Report.

The Observatory was founded in 1875 and is established in the park of Meudon, not far from Paris. It is by no means completed, so far as instruments are concerned, but its present facilities are employed in spectroscopic and photographic observations. Its distinguished Director and his assistants have taken part in many eclipse expeditions to all parts of the world, and M. JANSSEN has prosecuted his spectroscopic observations at all altitudes from the level of the sea, to the tops of the EIFFEL tower, of the Pic du Midi and of Mont Blanc.

The solar photographs of the Meudon Observatory are unrivalled. No description of them need be given here, because members of the society can see a beautiful glass copy of one of them which was presented to the Lick Observatory by M. JANSSEN, in a conspicuous place in the main hall of the Lick Observatory. E. S. H.

THE PROPOSED OBSERVATORY ON MONT BLANC.†

The group of Parisian scientists (writes the Lucerne correspondent of the *London Times*) led by M. JANSSEN, Membre de l'Institut, and including Prince ROLAND BONAPARTE and M. BISCHOFFSHEIM, are making preparations for a second attempt to realize their ambitious scheme of building an observatory on the summit of Mont Blanc. The operations last year, which

* M. JULES JANSSEN, Director.

† See *Publications* A. S. P., Vol. III, page 50.

resulted so disastrously to the workmen engaged, were principally confined to tunnelling through the snow just below the summit, with the object of discovering whether rock existed for a foundation. No such rock was found, and M. JANSSEN has now resolved to build the observatory in the frozen snow which covers the summit of the mountain. With a view to ascertaining whether this surface snow was sufficiently solid for the purpose, and whether any movement or displacement would be likely to occur after the construction of the observatory, a wooden cabin was erected on the proposed site at the end of last summer. This was visited in the month of January, 1892, and again early in the spring, but it was found that no movement whatever had occurred, and that the cabin had sustained no material damage. The promoters are, therefore, encouraged to build the observatory upon a similar foundation, and are convinced that the construction planned will resist all the elements, even at that altitude.

I have been favored with authentic particulars of the plan which it is proposed to pursue in carrying out this bold idea. The building proper for the observatory is now being constructed in Paris, and in another few days it will be brought in sections to Chamounix. The transport of the building from Chamounix to the summit of Mont Blanc and its erection there have been intrusted to the charge of two capable guides. They have already been to Paris in order to make themselves thoroughly acquainted with all the details of the construction. The observatory is to be a wooden building eight metres long and four metres wide, and consisting of two floors, each with two rooms. The lower floor, which is to be embedded in the snow, will be placed at the disposition of climbers and guides, and the uppor floor reserved for the purposes of the observatory. The roof, which is to be almost flat, will be furnished with a balustrade, running round it, together with a cupola for observations. The whole building will rest upon six powerful screw-jacks, so that the equilibrium may be restored if there be any displacement of the snow foundations.

Before the work of transportation from Chamounix to the summit begins two small cabins are to be constructed as resting places for the porters, one at the Grand Mulets, the other at the Roches Rouges. The latter cabin, which is 1000 feet below the summit, will be left standing for the future use of climbers, and, in addition, it is proposed to place there another building, octagon

in form, to be furnished with a cupola, to serve as a supplementary observatory. The promoters hope to be able to build these cabins and, with the exception of the cupola, to complete the observatory on the summit during the course of the present summer. But this necessarily depends upon the weather and upon the men obtainable for the work. Ordinary workmen, unaccustomed to the mountains, are of course useless, and there are many even of the Chamounix guides and porters who are incapable of remaining for any length of time at this great altitude. After the sad and fatal experiences of last year, the greatest care is to be exercised with regard to the health and safety of the men employed, in order to prevent, if possible, the loss of more lives in connection with this undertaking. Last summer, it will be remembered, an avalanche swept two of a caravan into a crevasse as they were returning from the summit, and an affection of the lungs contracted by Dr. JACOTET, who was sent to look after the workmen, caused his death in a few hours. The promoters, therefore, promise to insure at their own cost the lives of the men engaged upon the enterprise; the men are also to be paid 10f. a day, and in addition 3f. for every kilo carried from Chamounix to the summit. This pay is very liberal and very tempting, and it need be so when one considers the risks the men run. The storms and avalanches are terrible enough, but the chills and *mal de montagne* are even more dreaded. Men will, however, doubtless be found when M. JANSSEN arrives in Chamounix, a fortnight hence, to carry out the work.

—From *Edinburgh Scotsman* of 13th June, 1892.

STABILITY OF THE GREAT EQUATORIAL, 1888–1892.

Observations for the positions of the great telescope have been made by Messrs. SCHAEBERLE, KEELER and CAMPBELL, as below:

1888.	July 27,	azimuth = + 36″;	level = 8″ too low,
1889.	May 18,	azimuth = ...;	level = 36″ too low,
	Sept. 16,	azimuth = + 83″;	level = 58″ too low,
1890.	Aug. 23,	azimuth = (+ 54″);	level = 114″ too low.

Telescope adjusted—

1891.	June 30,	azimuth = + ?;	level = 35″ too low.

Holding-down bolts tightened—

1892.	Aug. 5,	azimuth = + 51″;	level = 25″ too high.

Note on the New Nebula in Auriga.

The 36-inch telescope was recently turned to the region of the interesting nebula, discovered by photography (see *Publ.* A. S. P., No. 22), connecting the stars W. B. 5^h, Nos. 151 and 162. It is safe to say that if the observers had not known just where to look for the nebula nothing unusual would have been noticed in the visual observations. None of the detail so plainly shown on the photographs can be recognized with certainty. Prof. Campbell found nothing unusual in the spectra of the two stars. J. M. S.

Appointment of Mr. Townley in the Lick Observatory.

Mr. S. D. Townley, B. S. (1890), M. S. (1892), of the University of Wisconsin, has been appointed Phebe Hearst Fellow in Astronomy in the Lick Observatory for one year from July 1, 1892. E. S. H.

A Graduate School of Astronomy at Mount Hamilton.*

"At this season, when we are hearing of so many summer schools of various sorts, it may be interesting to say a few words about the school of practical and theoretical astronomy which has grown up at Mount Hamilton as a part of the graduate system of the University of California.

"All the under-graduate instruction in astronomy in the university is given at Berkeley, where there is a capital students' observatory, well equipped with everything suitable for teaching the art of astronomical observation to college students. This students' observatory is under the charge of one of the instructors of the university who has himself received his training at the Lick Observatory and who arranges the courses at Berkeley so as to lead directly to higher work to be given at Mount Hamilton.

"Admission to the Graduate School is ordinarily granted to graduates of the University of California and also to graduates of other colleges of like standing, as well as to other persons of suitable age and attainments. Students at the Lick Observatory may either be candidates for some one of the higher degrees of the university (as Master of Arts, Master of Science, Doctor of Philosophy, etc.), or they may be special students seeking special instruction in some particular department of astronomy, which they have better opportunities to study at Mount Hamilton than elsewhere.

* Reprinted from the San José *Mercury*.

"The higher degrees mentioned are only given after a severe course of study which extends over three full years in the case of the Doctor's degree, for example; and even then they are not given for mere faithfulness in the performance of allotted tasks, but it is required that the candidate should show genuine power to advance knowledge by his original work, as well as acquire it from the work of others.

"The courses for special students are so arranged as to offer facilities to such professors and instructors in astronomy in other colleges as can afford to spend several months in actual work at Mount Hamilton, and it is a noteworthy fact that quite a number of such gentlemen—full professors, etc.—have already availed themselves of the opportunity. The Regents of the university have provided comfortable (unfurnished) quarters on the mountain and the only expenses to a student are his board (about $30 per month) and the cost of materials which he uses in his photographic and other work. As in all other departments of the University, the tuition itself is absolutely free.

"Mrs. HEARST has given a special fund to be used in aid of scientific work at the Lick Observatory, and a portion of this fund is available for paying a part of the necessary expenses of such advanced students as may be elected Fellows in astronomy by the Regents. Such Fellows are selected from students who have already made decided progress in their work and especially from those who are candidates for one of the higher degrees and who therefore intend to devote several years to the study of their profession.

"A list of the students now on the books of the observatory will give some idea of the class of persons who are attracted here and who find their best opportunities at Mount Hamilton and who, therefore, are no longer obliged to go abroad to seek what they want. They are:

"W. E. DOWNS, a graduate of the University of California, with the degree of B. S. in 1888, who is a candidate for the Doctor's degree.

"W. J. HUSSEY, a graduate of the University of Michigan, 1889, who is Assistant Professor of Astronomy in the Stanford University. Special.

"H. C. LORD, a graduate of the University of Wisconsin, 1889, who is instructor in astronomy in the State University of Ohio. Special.

"A. O. LEUSCHNER, a graduate of the University of Michigan, 1888, who is instructor in the University of California at Berkeley and who is a candidate for the Doctor's degree.

"D. W. MURPHY, a graduate of the Stanford University, 1892. Special.

"S. D. TOWNLEY, a graduate of the University of Wisconsin, 1890, and Hearst Fellow of Astronomy in the Lick Observatory, who is a candidate for the Doctor's degree.

"There are already several applications on file for admission to the observatory during the next year.

"It is clear from this list that a real need for a graduate school of the highest class exists in America; that the Lick Observatory is ready to fill the want and to give true university instruction after the more elementary college work has been done at Berkeley and elsewhere.

"It should be obvious to all Californians that their State University is growing by leaps and bounds in very many of its departments; and in no department, perhaps, more rapidly than in the Lick Observatory." EDWARD S. HOLDEN.

July 19, 1892.

TOTAL SOLAR ECLIPSE OF APRIL 16, 1893.

It is understood that the total eclipse of April 16, 1893, is to be observed by a French party under MM. BIGOURDAN and DESLANDRES in Senegal. The French Chambers have been asked to appropriate 17,000 francs for the necessary expenses.

It is probable that three parties will take station in Chili: namely, a party from the Arequipa station of the Harvard College Observatory; a Chilian party; and the Lick Observatory party under Professor SCHAEBERLE. So far as I know the stations of parties to be sent by the Royal Astronomical Society are not yet determined upon. At least one party from the Observatory of Rio Janeiro will observe the eclipse in Brazil, and it is possible that Professor PRITCHETT may again organize an expedition from Washington University, Saint Louis. E. S. H.

INVESTIGATION OF THE SYSTEMS OF BRIGHT STREAKS ON THE MOON.

Dr. OTTO BOEDDICKER, Astronomer of Lord ROSSE'S Observatory, has kindly offered to begin the study of the systems of

bright streaks on the moon, which was spoken of in these *Publications*, Vol. IV, page 81, so soon as he shall have received the necessary glass copies of the Lick Observatory photographs. These are now ready and will shortly be in his hands. The observatory is fortunate in promptly finding so able a co-adjutor.

E. S. H.

RESIGNATION OF DR. HENRY CREW.

Dr. HENRY CREW, Astronomer in the Lick Observatory, has resigned his position here and has accepted the appointment of Professor of Physics in the Northwestern University, Evanston, Illinois.

E. S. H.

POWDER EXPLOSION AT WEST BERKELEY, JULY 9, 1892.

The following account of the great explosion is copied from *Industry* for August, 1892:

"The Giant Powder Works plant, near West Berkeley, a suburban place on the northeastern coast of the bay, about eight miles from San Francisco, was blown up at nine o'clock A. M. on the ninth of July, and it is believed to be the most extensive explosion of the kind that has ever happened. Being situated on a spit of land projecting out into the bay there was a free course for air disturbance to the city, and other surroundings on the southern and western side of the bay, and windows were crushed for a distance of ten miles where no elevated land intervened. The air disturbance followed channels where the physical formation permitted horizontal flow, and even streets in the city seemed to have guided the lines of greatest effect.

"The loss of life was happily very slight compared with what might be expected, most of the people after the first explosion making their way to some distance, so that the force of the explosion passed over them. The number reported killed is less than ten, of whom all but three were Chinamen. It requires only a short time, and a little distance, to get without the active circle of explosions, which act upward at an angle of ten to twenty degrees, principally because of the material being partially below the surface of the ground, as in the case of magazines, also because the first effect is to excavate a pit the walls of which act as directing angles.

"The amount of material finished and in process is not

known, but was certainly not less than one hundred tons, some reports say several hundred tons."

In what follows I have collected and condensed a few typical accounts of the effects of the explosion. From these it is quite clear that the chief damage was done by an air-wave and that the wave transmitted through the ground was comparatively feeble. Dr. BECKER of the U. S. Geological Survey makes the very pregnant suggestion that the air-wave was reflected from the surface of the water of the San Francisco Bay and thus deflected upwards against the face of the high hills on which the city is built. The powder works were themselves built on high bluffs.

The explosion of anything like this amount of dynamite, if it had been buried in the ground, would have produced an earth-wave which would have been felt at Mount Hamilton. But with all the explosives above ground, as they were, no such effect could be expected. The wave-front of the air-wave must have contained an enormous energy, but when this wave-front reached the summit of Mount Hamilton it was so enlarged that no certain record of its passage can be found on our self-recording barometer sheets. I have, as yet, seen no notice of barometric observations of the air-wave in San Francisco and adjacent points though such may have been secured. The Technical Society of the Pacific Coast has considered this explosion at its meeting in July and reference is made to the *Transactions* of this Society (which I have not seen at the time of writing) for details. The present note is chiefly designed to record the fact that no effects from this tremendous explosion were felt at Mount Hamilton. (See also, *Publications* A. S. P., Vol. III, page 132.)

San Francisco. It is more than eight miles from Fleming's Point to San Francisco, the line joining the two points being mostly over water. At least five distinct shocks were felt in the city and so severe were they that hundreds of panes of heavy plate glass were broken in the lower portion of the town. Immense iron-doors of warehouses were forced open. Buildings swayed to and fro sufficiently to frighten their occupants. Two of the iron doors of the Mint were twisted from their hinges. Every gas-light in the City Jail (and in other buildings) was extinguished by the rush of air after the last explosion.

Oakland Pier. The explosion was witnessed in part by one of our astronomers who was a passenger on the overland train, just entering Oakland Pier. The first explosion was compara-

tively slight; but at a distance of seven miles there was a sharp report and at the same instant the heavy Pullman car was rocked sidewise. Emerging from behind an obstruction, Fleming's Point was in clear view across the Bay. Suddenly a sheet of flame rose at least 100 feet, and about 20 or 25 seconds later the report reached the train, the car was very violently rocked, and the windows rattled. The last two shocks occurred a few minutes later, when the passengers were on the boat in the slip. Their intensity was very much greater than that of the first shocks. The reports were sharp and strong, the buildings creaked under the great strain, and the ferry boat rocked very perceptibly though it was protected by the buildings from the direct air-wave.

In all cases the report and the shock were simultaneous, showing that the shock was transmitted by the air and not through the water.

Oakland is about 8 miles distant. Thousands of panes of window-glass were shattered in private houses, but no serious damage was done to buildings or persons. At the Chabot Observatory, Mr. BURCKHALTER'S earthquake instrument gave a small mark like a V. An *earthquake* giving a mark like this would be a small affair.

Berkeley. The State University is 4 miles distant. Nearly all the window-glass in the college buildings was destroyed. As it was vacation-time the earthquake instruments were not (I believe) in operation and no record of the disturbance was obtained.

East Oakland. Mr. BLINN'S earthquake instrument had its pen thrown entirely off the glass plate. A pipe lying on a shelf in his observatory was thrown to the floor. Mr. BLINN writes that "a great air-wave accompanied the explosion, though no "mention of this appears in the papers. I was told of a man in "East Berkeley who was working on a lumber-pile, which was "thrown down with him, and he says the air-wave threw it over "and not the shock of the ground."

Healdsburg is 55 miles distant. A distinct shock was felt here, which was unlike that of an earthquake. It was called an "air-wave" in the first telegrams.

Sonoma is 25 miles distant. Panes of window-glass were broken here.

Sacramento is 60 miles distant. No damage was reported,

though the shock was sufficiently severe to cause persons to rush out of the very substantial Capitol building in terror.

San Rafael is 13 miles distant. Buildings were slightly damaged.

Duncan's Mills is 50 miles distant. The shocks were distinct and were supposed to be earthquakes.

Mount Hamilton is 50 miles distant and 4200 feet higher, with many ranges of hills lying between. No record appeared on the large EWING seismograph. The duplex instrument shows a very small mark which is possibly due at least in part, to the explosion. It is, however, so small that it may be entirely due to the shifting of the pen by temperature, etc. I have examined the sheets of the DRAPER Self-Registering Barometer and find an exceedingly small change in the pencil line a little after $9^h\ 30^m$, but it is very doubtful if this change corresponds to the arrival of the air-wave, since there are other such marks on the same sheet at other times of this day.

E. S. H.

THE APPLICATION OF INTERFERENCE METHODS TO SPECTROSCOPIC MEASUREMENT, BY PROFESSOR MICHELSON.

The following report of a paper read by Professor MICHELSON in Edinburgh on August 6, is from the *Edinburg Stotsman* of August 8, 1892.

"The principal paper of the day was by Mr. A. MICHELSON, Professor-elect of Chicago University, on the application of interference methods to spectroscopic measurement. The ordinary methods of producing dispersion, such as by the prism or grating, sufficed, he explained, to separate lines when their distance apart was a fiftieth of the distance between the two sodium lines. In order to get more precise results, it would be necessary to multiply the size of the grating according to the degree of precision required. For the purposes of his investigation he had devised an apparatus which he called a wave compiler, which enabled him to produce interference of the rays which were being examined, and by altering the distance of the paths of the rays to vary the clearness of the interference fringes. If the light under examination were made up of two distinct sources, as in the case of sodium, a regular and periodic variation was obtained. If such a periodic variation was seen in the clearness of the fringes, they might argue with certainty that the light was a double one. Extending the investigation still further, if the curve was of any form, no matter how

complex, then by mathematical relations Professor MICHELSON showed that they could deduce the form or distribution of the light, whether it was double, as in the case of sodium; or triple or quadruple, as in the case of other substances. He had experimented upon various substances—hydrogen, oxygen, sodium, zinc, cadmium and mercury—and in almost all cases he had found that the lines which appeared in the most powerful spectroscopes to be single, were doublets or triplets, and in some cases very much more complex. In the case of hydrogen, especially, they could alter the temperature and pressure with facility, and on examining the visibility curve of hydrogen he had found that the distribution of light in the source, deduced from these curves, was such as to indicate that the width of the component lines diminished as the pressure diminished, though not indefinitely, but approached a certain limit. This seemed to indicate that this limit, according to the kinetic theory, depended on the temperature of the gas. A much stronger confirmation of the truth of the theory was furnished by the application of DÖPPLER'S theory of the vibration of the radiating molecules of the substances examined. It had been argued that the fact of being able to get interference with such a wide difference of path—this difference of path had been increased from some 50,000 waves up to about 800,000 or 900,000—was that the effect of the motion of the molecule in the line of sight must be negligible, and that therefore the kinetic theory of gases, which was based upon that theory, must be wrong. A comparison of radiations from over twenty different substances gave numbers which in every case were of the order of magnitude required by the kinetic theory. This, perhaps, might be considered as the most direct proof that existed of the motion of the gaseous molecule.

"Professor MICHELSON'S wave compiler consists essentially of a plane parallel glass and two mirrors. Light from the radiating substance impinges on the plane parallel glass at an angle of 45°, and is partly reflected and partly transmitted, the two pencils striking the two mirrors at normal incidence, and being reflected back each on its own path, falling again upon the plane parallel plate, and there re-uniting to form a beam of light which can be observed by the eye or the telescope. One of the mirrors is moved in such a way as to be kept parallel with itself by means of a slow motion screw, thus producing a difference of path which causes a change in the clearness of the interference fringes from

which the distribution of light before described is obtained. The PRESIDENT, in remarking upon Professor MICHELSON'S apparatus afterwards, said it seemed to increase the use of spectroscopic powers without the use of enormous prisms. The lines on ROWLAND'S instrument would require to be ruled across two feet in order to give the results which Professor MICHELSON obtained on a small surface."

NOVA AURIGÆ.

The new star which appeared in the constellation *Auriga* last winter gradually faded away until when last observed in April it was about the sixteenth magnitude. It was re-observed the morning of August 18 by Professors HOLDEN, SCHAEBERLE and myself, and found to have increased in brightness to about the 10.5 magnitude. All the observers agreed that its appearance differed from that of other stars of the same brightness in that its disk was larger and its light duller, but the moonlight interfered with further study of its character, and a small spectroscope was at once put on the telescope. The spectrum with weak dispersion consisted of three bright lines and a very faint continuous spectrum. The morning of August 20 I further examined its spectrum with a more powerful spectroscope attached to the 12-inch equatorial. One of the bright lines previously seen was resolved into three bright lines, which were at once recognized as the three characteristic nebular lines. The continuous spectrum was scarcely brighter than that of a twelfth magnitude star. Visual observations by Professor BARNARD with the 36-inch equatorial on the same morning also showed that the star is a nebula about three seconds of arc in diameter, with a stellar nucleus of the tenth magnitude, and that it has not moved appreciably since last March.

Further observations of the spectrum are in progress. The positions of the three nebular lines and seven other bright lines have been quite accurately determined. The positions of the three nebular lines would indicate that the nebula is moving towards us with a great velocity—about 175 miles per second.

The general character of the spectrum justifies us in calling this interesting object a planetary nebula. Whether we are to witness any further evolution remains to be seen. The broad and hazy character of the bright lines, and a number of peculiarities in their positions, give some promise of further changes. W. W. C.

A Correction—by Edward S. Holden.

Unauthorized statements with regard to the Lick Observatory observations of *Mars* have been telegraphed over the United States with the result that astronomers and others are temporarily holding false impressions of our scientific results which I desire to correct. The circumstances were as follows:—

On the evening of July 30, an employé of a San Francisco newspaper asked me by telephone to answer certain questions with regard to *Mars*. I did so briefly. My replies were evidently misunderstood, for the Editors sent out telegrams containing various errors to the Directors of other observatories. One of these telegrams read as follows:—

(dated) San Francisco, July 31, 1892.

To

—— ——, Director of —— Observatory:

"Director Holden, Lick Observatory, *announces* that pre-"sent observations show Mars' satellites in eclipse and that *each* "*satellite moves its own diameter in two-tenths of a second; also* "*that canals not double*. Will you kindly telegraph result your "observation and what you think Holden's *announcement?* "Send dispatch collect."

(Signed) ——— ———

I have italicized certain words of this dispatch to direct attention to them. I "announced" nothing as a final result; I said nothing regarding the satellites' diameters; I made no statement that the canals were not double at all, since I knew beforehand that some of them were. Eclipses of the satellites were no new things, since they were observed here in 1890. The effect of this dispatch might be to stop or to hinder observations at observatories less favorably situated than our own; it misrepresented the work of the Lick Observatory; it did a great injustice to our honored correspondent, Professor Schiaparelli, the discoverer of the double canals.

I therefore felt it proper to send a dispatch to the Manager of the Associated Press—especially as inquiries began to pour in upon us with regard to "announcements" for which we were not responsible,—to say that we were responsible for such dispatches only as were signed by us.

The necessity for some such disclaimer is emphasized by the fact that on August 17 and succeeding dates the canals of *Mars* have been seen to be doubled here in 1892 as they had been in 1890. Thus the Lick Observatory has twice confirmed Professor SCHIAPARELLI'S discoveries of 1877 and 1881.

OBSERVATIONS OF THE OCCULTATION OF *MARS* SEPT. 3, 1892, AT MOUNT HAMILTON.

N. B.—The times are Pacific standard times = G. M. T. — 8 hours.

With the 36-inch Equatorial.

Immersion, with 36-inch equatorial, power 350.

Contact I, $9^h\ 16^m\ 8^s.3$ Pacific standard time.
" II, 9 17 12.6 " " "

The disk of *Mars* disappeared at $9^h\ 17^m\ 11^s.1$ A straight line of light about equal in length to the diameter of *Mars* remained on the moon's limb for $1^s.5$ after the disk disappeared.

Emersion, with finding telescope of 36-inch equatorial.

Contact III, $10^h\ 32^m\ 28^s.1$ Pacific standard time.
" IV, 10 33 29.4 " " "
Duration . . . 1 16 18.3.

W. W. CAMPBELL.

Contact.	Pacific Standard Time.
1st	Sept. 3, $9^h\ 16^m\ 5^s.6$
2d	9 17 12.6
3d	10 32 26.1
4th	10 33 25.8
Duration	1 16 16.8

For the first and second contacts the 4-inch finder (Power 25) attached to the tube of the great telescope was used. The third and fourth contacts were observed through the 36-inch telescope using a power of 350 diameters. Just before the disappearance at second contact the limb of *Mars* appeared blurred. After third contact the difference between the colors of the moon and *Mars* was strikingly shown, *Mars* having a dull red appearance compared to the brilliant yellow of the moon.

J. M. SCHAEBERLE.

With the 12-inch Equatorial.

I................	9^h	16^m	$10^s.1$;	E. E. BARNARD.
II................	9	17	11 .4;	"
Center *Immersion*..	9	16	40 .7;	"
III	10	32	30 .3;	"
IV................	10	33	26 .8;	"
Center *Emersion*...	10	32	58 .5;	"
Duration	1	16	17 .8.	

With the 6½-inch Equatorial.

I................	9^h	16^m	$11^s.5$;	C. BURCKHALTER.
II................	9	17	12 .5;	"
Center *Immersion*..	9	16	42 .0;	"
III	10	32	33 .3;	"
IV................	10	33	30 .3;	"
Center *Emersion*...	10	33	1 .8;	"
Duration	1	16	19 .8.	

"The following limb of *Mars* appeared to lag 1^s" at Contact II.

With the 3¼-inch Portable Telescope.

I................	Time not recorded.			
II................	9^h	17^m	8^s;	F. R. ZIEL.
III...............	10	32	38 ;	"
IV	10	33	30 ;	"
Center *Emersion* ..	10	33	4 ;	"

With the Naked Eye.

Emersion took place 23½ seconds after Contact IV. Observers, C. BURCKHALTER and (independently) Rev. M. C. WILCOX.

CORRECTIONS OF THE LICK OBSERVATORY TIME-SIGNALS.

As the Lick Observatory time-signals might be used by others for the observation of this phenomenon, Mr. S. D. TOWNLEY took especial pains to have the transmitting clock right at the time of the noon-signal.

Its correction at noon, September 3 was $+0^s.01$.
" " " " " 4 was $+0.02$.

Preliminary Note on the Observations of the Surface Features of *Mars* during the Opposition of 1892, by J. M. Schaeberle.

My observations on the planet *Mars* were commenced on June 11 and have, with some interruptions, been continued up to the present time. The planet has also been more or less regularly observed by the other astronomers of this observatory and also by Professor Hussey. In this note, however, only my own observations and views come under consideration. These views may be considerably modified by the observations still to be made during the present year, so that no definite statements as to the character of the final results can be made before the end of October.

Remarkable surface changes have certainly been going on in the south polar regions of *Mars*. The character of these changes almost forces one to the conclusion that great areas in the polar region are covered with congealed matter very similar in nature to some of the forms of water at certain temperatures on the earth's surface. A series of drawings showing the character of these changes, some of which were shown to the Society at our last meeting, will be published later on.

In this note I wish particularly to point out a rather singular contradiction which has almost persistently presented itself to my mind during the whole time that these observations have been going on. Schiaparelli, Flammarion and observers of *Mars* in general agree, I believe, in calling the darker areas of *Mars* water and the brighter portions land—at least one is led to this conclusion by the nomenclature almost universally used in describing the various surface features of *Mars*.

My own observations have led me to incline to just the opposite view. Some of the reasons for coming to such a conclusion are given below.

1st. If the dark markings are water how are we to explain the irregular gradations of shade which, according to observation, are fixed surface features?

2d. If the dark markings are land just such observed gradations would naturally be expected.

3d. Light reflected from a spherical surface of water in a slight state of agitation would vary uniformly in intensity. At opposition the center of the planet would, for a water surface, appear

brightest. Observations show that within a certain distance from the edge of *Mars* there is a gradual increase in the steady lustre of the brighter areas towards the center of the planet.

4th. If the dark areas are water, they should according to the preceding paragraph be least dark near the center, but observations show that these markings are most conspicuously dark and the contrasts between light and shade most strong near the center of the disk.

5th. At certain times which can not be predicted, whole areas of limited extent, corresponding to portions of bright areas, and usually bounded on two or more sides by darker markings are seen to be more brightly illuminated than other portions of the disk as though the reflecting surface was in a state of agitation suitable for causing the observed phenomena (like the contrasts which result between the conditions due to light reflected from a calm and from an agitated water surface). Excepting the polar regions, such changes have invariably been noticed, by me, in the brighter areas only.

6th. Crossing the darker areas are still darker streaks which often extend hundreds of miles in nearly straight lines. One end of a given streak usually terminates in the equatorial region at a point where the dark area protrudes into the bright area, and the so-called canals seem to be continuations of the streaks. Where these dark streaks seem to intersect the limb of *Mars* the white areas projecting beyond the terminator of *Mars* (often noticed in June and July during the partial phase) were usually seen, indicating that the dark streaks were elevated above the general surface and rendered more bright by being projected against a dark background. That the bright areas projecting beyond the terminator actually lie in a dark streak needs further confirmation.

7th. The fainter markings called *canals* would, on this hypothesis, correspond to the ridges of mountain chains which are almost wholly immersed in water. The doubling of these markings represents parallel ridges of which our own earth furnishes examples. These fainter markings usually end in, or converge to, a conspicuous dark area which may be of very limited extent. As stated above, they usually begin at some protruding dark area formed by the junction of two or more dark streaks as though the canals were continuations of the streaks. The narrowness of the visible parts would account for the difficulty of seeing them.

8th. As a concluding argument in favor of the theory that the dark parts are land and the brighter areas water, I take an observed terrestrial phenomenon.

About twenty-five miles to the northwest of Mt. Hamilton is the lower end of San Francisco bay. In fair weather the whole country from Mt. Hamilton to San Francisco, a distance of fifty miles, is plainly visible. Now at all hours of the day *the surface of San Francisco Bay* (as seen from the top of Mt. Hamilton) *is much brighter than the neighboring valley and mountains at the same distance*, although the line of sight makes an angle of more than 87° with the normal to the surface of the bay and the observer's position varies all the way from being nearly in a direct line between the bay and the sun to the position in which the sun is nearly in the direction of the bay.

The internal reflections in an atmosphere not perfectly transparent would tend to render an underlying water surface much brighter than a surface of land in the same position.

As stated above these views may be modified somewhat by the observations still to be made during the present year.

LICK OBSERVATORY, Sept. 3, 1892.

NOTICE TO MEMBERS.

The edition of Numbers 1 and 2 of our *Publications* is exhausted. We have, however, quite a number of copies (some 200) of Nos. 3, 4 and 5 on hand. Volume I of the *Publications* comprises Nos. 1, 2, 3, 4, 5. If a sufficient number of persons signify their desire to purchase Volume I complete (price $2), the lacking numbers of the *Publications* will be reprinted and the volume distributed. Such orders should be addressed to

The Committee on Publication A. S. P.,

Mount Hamilton, California.

OCCULTATION OF *JUPITER* AND HIS SATELLITES, SEPT. 8, 1892.

The observations recorded below were made with the 36-inch refractor using a power of 700 diameters. The seeing at the ingress of satellite I was very good, but the other observations were made under less favorable atmospheric conditions. The immersions occurred just before sunrise. The emersions were

not looked for as the phenomena took place in broad daylight with poor seeing.

Object.		Pacific Standard Times of Ingress. 1st Limb.	2d Limb.
Satellite III.	Sept. 8.	$17^h\ 17^m\ 21^s.4$	$17^h\ 17^m\ 24^s.5$
Satellite IV.		17 29 38.2	Blurred
Satellite I.		17 30 56.7	17 30 58.7
Jupiter		17 34 44.1	17 36 22.5
Satellite II.		17 45 4.2	17 45 6.7

As the bright disk of the moon gradually passed over the pale surface of *Jupiter* the spherical form of the latter was very conspicuously brought out. The belts appeared almost black by contrast. No distortions were observed.

Satellite I is elongated in the direction of *Jupiter's* equator.

Satellite III has a bright polar cap near the north point of its disk much resembling the polar cap as seen on *Mars* during June and July.

J. M. S.

DISCOVERY OF A FIFTH SATELLITE OF *JUPITER* BY PROFESSOR BARNARD.

The following telegram was sent on September 11.

(dated) LICK OBSERVATORY, Sept. 11, 1892.

The Lick Observatory desires to announce that Professor BARNARD has added a fifth satellite to the four satellites of *Jupiter* discovered by GALILEO on January 7, 1610. It was discovered by BARNARD on September 9th. Its period is about $12^h\ 36^m$.* Its distance from the planet's center is about 112,400 miles. It was observed by him at east elongation September 10, $20^h\ 53^m\ 21^s$ Greenwich mean time. Its magnitude is the thirteenth.

* Later observations give the period as about 11 hours 50 minutes.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD AT THE LICK OBSERVATORY, SEPT. 3, 1892.

President SCHAEBERLE took the chair; and a quorum was present.

The minutes of the last meeting were approved.

Mr. FRANK MCCLEAN, of Tunbridge Wells, England, was elected a life-member.

The following members were elected. An asterisk (*) is added to the name of life-members.

LIST OF MEMBERS ELECTED SEPTEMBER 3, 1892.

ELMER A. ALLOR	Observatory, Ann Arbor, Mich.
CHARLES ALTSCHUL	London, Paris and American Bank, S. F., Cal.
E. M. ANTONIADI	Constantinople, Turkey.
J. BASSETT	82 High St., Stoke Newington, N. England.
D. P. BELKNAP	405 Montgomery St., S. F., Cal.
EDWIN BERGH	429 5th Ave., New York, N. Y.
Mrs. JOHN JAY CHAPMAN	327 W. 82d St., New York, N. Y.
C. H. COCHRANE	18 Astor Place, New York, N. Y.
*Dr. GEORGE W. COOK	131 53d St., Chicago, Ill.
F. W. DOHRMANN	Alameda, Cal.
Miss DUNHAM	37 E. 36th St., New York, N. Y.
JOSEPH G. EASTLAND	920 Pine St., S. F., Cal.
FRANKLIN FAIRBANKS	St. Johnsbury, Vermont.
F. H. FERRINGTON	36 Albert St., Shrewsbury, Eng.
ROBERT ISAAC FINNEMORE, F. R. A. S.	Durban, Natal, South Africa.
Sir GEORGE GREY, K. C. B.*	Auckland, New Zealand.
W. C. GURLEY	Marietta, Ohio.
E. F. HAAS	Berkeley, Cal.
Judge C. M. HAWLEY	5326 Washington Avenue, Chicago, Ill.
HENRY C. HAWTREY	Greycliff, Bonchurch, Isle of Wight, England.
HENRY S. HULBERT	Probate Court, Detroit, Mich.
NELS JOHNSON	Manistee, Mich.
Miss FLORENCE BAYARD KANE	Chestnut Hill, Philadelphia, Pa.
FR. KOEPPEN	Potsdamer St. 65, Berlin, Germany.
Prof. LOUIS LISSER	1241 Franklin St., S. F., Cal.
FRANK E. LUNT	Care R. G. Lunt, Los Angeles, Cal.
ROGER D. MAGEE	20 Montgomery St., S. F., Cal.
ARTHUR MEE, F. R. A. S.	Llanelly, Caermarthenshire, Great Britain.

Prof. E. MILLER	University of Kansas, Lawrence, Kansas.
MILO H. MILLER	McKeesport, Allegheny Co., Pa.
OXFORD COLLEGE	Oxford, Ohio.
C. PUDDEFOOT	Champlain and Brush Streets, Detroit, Mich.
Dr. T. STEELE SHELDON, F. R. A. S.	Parkside, Macclesfield, Eng.
STEPHEN H. SMITH	428 California St., S. F., Cal.
Rev. GEORGE STOKES	St. John's Vicarage, Isleworth, Middlesex, England.
S. H. STRITE	1112 Leavenworth St., S. F., Cal.
J. P. TREANOR	320 Sansome St., S. F., Cal.
Colonel B. WITKOVSKY*	St. Petersburg, Petersburg Side, Great Prospect h. 8, l. 5, Russia.

The Treasurer presented his report which was received and filed.

The following resolution was adopted by a unanimous vote of the Board of Directors,—

Resolved, That the By-Laws (Article II) be amended by abolishing the status of Honorary and of Corresponding Members and making the necessary verbal changes (see *Publ.* A. S. P., Vol. III, page 194).

The life-membership fee which was transferred to the General Fund (see *Publ.* A. S. P., Vol. III, page 381) was, on motion, ordered transferred back to the Life-Membership Fund.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD AT THE LICK OBSERVATORY, SEPTEMBER 3, 1892.

President SCHAEBERLE presided.

The minutes of the last meeting, as printed in the *Publications*, were approved.

A list of presents was read by the Secretary, and the thanks of the Society were voted to the givers.

Special attention was called to an enlarged transparency on glass (twenty inches square) of the moon and an enlarged positive on glass of *Jupiter* presented by the Lick Observatory, and to a number of photographs representing the buildings and instruments of the Lick Observatory, presented by HENRY E. MATHEWS.

The Secretary read the names of members duly elected at the meeting of the Directors.

The following papers were presented:—

1. The Partial Eclipse of the Moon of May 11, 1892; by A. STANLEY WILLIAMS, F. R. A. S.
2. The effect of Parallax on the Phenomena of the Satellites of *Mars*; by Professor HUSSEY, of the Stanford University.

3. Lick Observatory Photographs of *Jupiter*, 1891; by A. STANLEY WILLIAMS, F. R. A. S.
4. Discovery of a New Crater on the Moon-Negatives of the Lick Observatory; by Professor WEINEK, of Prague. (Translation by F. R. ZIEL.)
5. Note on the August Meteors of 1892; by Professor KIRKWOOD, of Riverside.
6. A Suggestion to University Instructors of Classes in Astronomy; by C. B. HILL, of San Francisco.
7. Recent Observations of *Nova Aurigæ:* Comparison of its Present Spectrum with that of February and March; by W. W. CAMPBELL, of the Lick Observatory.
8. Lick Observatory Observations of *Mars* in 1892: a Preliminary Discussion; by J. M. SCHAEBERLE, of the Lick Observatory.
9. Variable Stars of Long Period; by S. D. TOWNLEY, Hearst Fellow in Astronomy in the Lick Observatory.

Adjourned.

OFFICERS OF THE SOCIETY.

J. M. Schaeberle (Lick Observatory), ... *President*
E. J. Molera (850 Van Ness Avenue, S. F.), ... } *Vice-Presidents*
Frank Soulé (Students' Observatory, Berkeley), ... }
Otto von Geldern (819 Market Street), ... }
W. W. Campbell (Lick Observatory), ... *Secretary*
F. R. Ziel (410 California Street, S. F.), ... *Secretary and Treasurer*

Board of Directors—Messrs. Alvord, Campbell, Hill, Holden, Camilo Martin, Molera, Pierson, Schaeberle, Soulé, Von Geldern, Ziel.

Finance Committee—Messrs. Pierson, Martin, Ziel.

Committee on Publication—Messrs. Holden, Campbell, Yale.

Library Committee—Messrs. Molera, Von Geldern, Hill.

Committee on the Comet Medal—Messrs. Holden (*ex-officio*), Schaeberle, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Messrs. Douglass (Chairman), Ewell, Hale (Secretary), Pike, Thwing.

NOTICE.

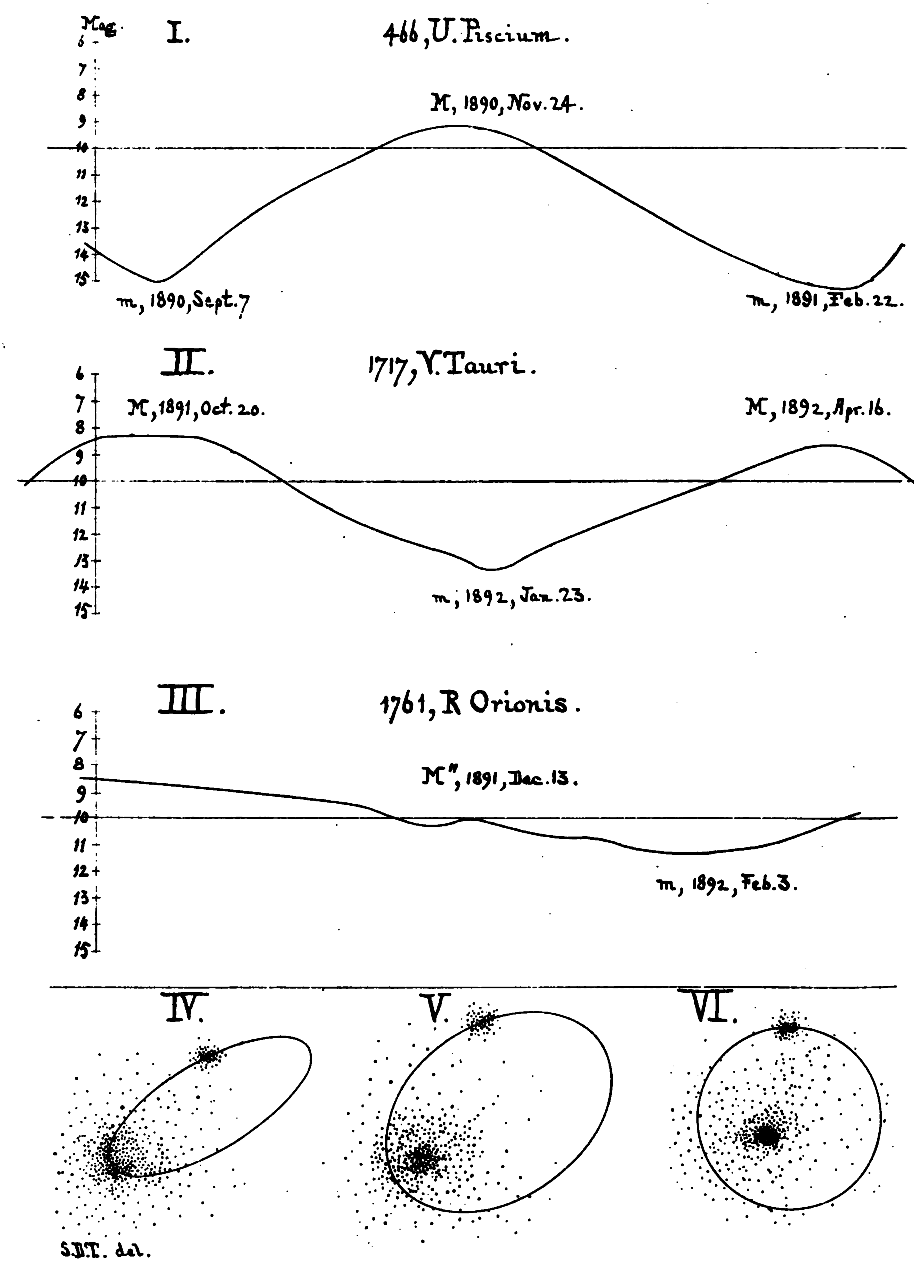
The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.


I.
466, U. Piscium.
Mag.
6
7
8
9
10
11
12
13
14
15
M, 1890, Nov. 24.
m, 1890, Sept. 7
m, 1891, Feb. 22.
II.
1717, V. Tauri.
6
7
8
9
10
11
12
13
14
15
M, 1891, Oct. 20.
M, 1892, Apr. 16.
m, 1892, Jan. 23.
III.
1761, R Orionis.
6
7
8
9
10
11
12
13
14
15
M", 1891, Dec. 13.
m, 1892, Feb. 3.
IV.
V.
VI.
S.D.T. del.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. IV. SAN FRANCISCO, CALIFORNIA, NOVEMBER 26, 1892. NO. 26.

VARIABLE STARS OF LONG PERIOD.

BY S. D. TOWNLEY, M. S.; HEARST Fellow in Astronomy, LICK Observatory.

In order to study the phenomena of variable stars numerous classifications have been proposed, but the most complete and the one now most generally used is that of Professor EDWARD C. PICKERING, Director of the Harvard College Observatory.

The classification is as follows: *

"I. Temporary stars. Examples: Tycho Brahé's star of 1572, new star in Corona, 1886; [also *Nova Aurigæ*, 1892].

"II. Stars undergoing great variations in light in periods of several months or years. Examples: *o Ceti* and χ *Cygni*.

"III. Stars undergoing slight changes according to laws as yet unknown. Examples: α *Orionis* and α *Cassiopeiæ*.

"IV. Stars whose light is continually varying, but the changes are repeated with great regularity in a period not exceeding a few days. Examples: β *Lyræ* and δ *Cephei*.

"V. Stars which every few days undergo for a few hours a remarkable diminution of light, this phenomena recurring with great regularity. Examples: β *Persei* (Algol) and S *Cancri*."

The second class, stars undergoing large variations of light in periods of several months, or variable stars of long period, forms the subject of discussion in this paper. Stars having periods of more than fifty days fall into this class, and those having periods of less than fifty days come under either the fourth or fifth class. This line of division is not entirely arbitrary, for the long periods

* Proc. Amer. Acad. xvi, 1.

are mostly greater than three hundred days, and the majority of short periods are less than twenty days.

LENGTH OF PERIOD. CHANDLER'S Catalogue of Variable Stars (1888) contains one hundred and thirty-two stars that belong to the long period class. The shortest period is sixty-five days, and the longest seven hundred and thirty days, but between these limits the stars are not uniformly distributed, as the following table will show:

Period.—Days.	Number.	Per Cent.
50—100	5	3.8
100—150	6	4.6
150—200	10	7.6
200—250	16	12.1
250—300	20	15.2
300—350	30	22.7
350—400	24	18.2
400—450	12	9.1
450—500	5	3.8
500—550	0	0.0
550—600	1	0.8
600—650	1	0.8
650—700	0	0.0
700—750	2 *	1.5
Total	132	100.1

* My observations show the period of 5430, T *Libræ*, to be 244 days rather than 723 days, as given in CHANDLER'S Catalogue. The period of 5688. R *Libræ*, given as 730 days, is very uncertain, so that the longest period yet determined with certainty is that of 432 S *Cassiopeæ*, 607.5 days.

This table shows that periods of about a year largely predominate, forty-one per cent. of all being between three hundred and four hundred days. The mean of the periods, excluding those of T *Libræ* and R *Libræ*, is three hundred and three days. A graphical representation of the data set forth in the table shows that the distribution of periods is very closely represented by GAUSS' error curve; and this, together with the fact that the highest point of this curve corresponds to periods of about a year in length, cannot be looked upon as entirely fortuitous and are two important points that must be kept in mind by him who would attempt to formulate a theory to explain this kind of stellar variability.

VARIATION OF PERIOD. The length of period in stars of this class is usually not constant. If two maxima of a star have been observed and its period thus determined, it is quite probable that future observations will show deviations from this period amounting to several days or weeks, so that the period derived will need to be corrected by some secondary term.

If the recurrences are perfectly uniform then the time of any maximum or minimum can be computed from the equation,

$$T_1 = T_0 + PE,$$

in which T_0 is an observed time of maximum or minimum, P the period of variation and E the number of periods passed through since the time T_0. If, however, the period of the star is increasing or decreasing, then the equation will be modified to the form,

$$T_1 = T_0 + PE + cE^2,$$

in which c is a constant to be determined from the observations, positive if the period is increasing and negative if the period is decreasing. As the number of observations is increased, perhaps the third and fourth powers of E may be added.

If the changes in the period are themselves variable, then the variations cannot be represented by this equation, and recourse to the sine or cosine functions becomes necessary. The equation will then assume the form,

$$T_1 = T_0 + PE + c \sin (bE + d),$$

c, b and d being constants to be determined from the observations.

The star 4826, R *Hydræ*, shows changes of both a secular and a periodic nature, and its observed variations can be represented by the equation,

$$T_1 = T_0 + 496^d.91\,E - 0^d.2307\,E^2 - 0^d.001276\,E^3 + 80^d.5 \sin (4^\circ.3\,E + 353^\circ.7).$$

It is highly probable that all the stars of this class will show variations of period of either a secular or a periodic character or both, but the vast majority of them have not been observed sufficiently to determine the form of these variations, and until further observations are obtained can be represented only by a mean period.

AMOUNT OF VARIATION IN BRIGHTNESS. The amount of change in variables of this class is usually from five to eight magnitudes, although in some the change is small, that of 7754,

W *Cygni*, being from four-tenths to six-tenths of a magnitude in a period of one hundred and twenty-six days. The amount of change in any particular star is not constant, and the range between different maxima and different minima usually is about a magnitude.

For 513, R *Piscium*, the range at maximum, according to CHANDLER'S Catalogue, is from $7^m.0$ to $8^m.8$ and I have observed two minima of the star, 1891, January 8 at $16^m.2$ and 1891, December 8 at $14^m.0$, a range of over two magnitudes.

Of 466, U *Piscium*, I have observed three maxima and three minima, as follows:

Maxima.	Minima.
1889, Dec. 17, 9.5 mag.	1890, Sept. 7, 14.5 mag.
1890, Nov. 24, 9.4 "	1891, Feb. 22, 14.7 "
1891, Nov. 8, 9.4 "	1892, Feb. 9, 14.7 "

These show a range of but one-tenth of a magnitude at maximum and of two-tenths at minimum. Both of these illustrations are extreme cases.

FORM OF LIGHT CURVE. The light curves of this class of variables are all alike in general form, but differ somewhat in particulars. Some have flat maxima, and others sharp ones; some have flat maxima and sharp minima, or *vice versa*. The curve of any particular star is not always the same, for one maximum may be flat and the next one sharp. In nearly all the rise from minimum is more rapid than the fall from maximum, and it has been found that the ratio of these two parts of the period is, in general, five to six. The above points are illustrated by the curves in the plate, taken from my own observations.

The curve of 466 is very regular, and illustrates the relation of the two parts of the curve, the time from minimum to maximum being seventy-eight days, and from maximum to minimum ninety days, a ratio which agrees closely with that given above.

The curve of 1717 is somewhat irregular, the first maximum being very flat and the second one rather sharp.

In a large number of the stars of this class there is a tendency for the curve to flatten out after passing the maximum, and this tendency in some cases even goes so far as to result in a secondary maximum, as is illustrated by Figure III.

COLOR. Mr. CHANDLER has determined the color of a large number of variable stars, and the result of his work shows some

important facts. Nearly all variables of the long period class are of a red color, and it was this fact that led to a more detailed investigation. The colors of the stars are denoted by the numbers from zéro to ten, the meaning of which can be explained best by the following quotation, taken from CHANDLER's Catalogue of Variable Stars, page 3: "The redness is expressed to tenths of a degree of an arbitrary decimal scale, the zero of which corresponds to white light, and the other limit, ten, to the most intense shade of red of which we have cognizance in the heavens, exemplified by such stars as S *Cephei*, V *Cygni*, and R *Leporis*. As nearly as the intermediate degrees of this imaginary scale can be verbally defined, 1 corresponds to the slightest perceptible admixture of yellow with the white; 2 to a yellow; 3 to yellowish orange; 4 to a full orange or orange red; and 5 to 10 to increasing shades of intensity up to the limit described."

From the Catalogue I have taken all the long period variables of which Mr. CHANDLER has determined the redness and tabulated them in the following table. In the third column is given the mean redness of the stars whose periods lie between the limits expressed in the first column. In the fourth column is the redness graphically adjusted, and in the second column is given the number of stars upon which the mean depends.

Period.—Days.	Number.	Redness.	Adj. Redness.
50—100	3	1.3	1.3
100—150	3	1.4	1.5
150—200	7	2.2	1.8
200—250	8	2.1	2.3
250—300	16	3.1	2.9
300—350	25	3.5	3.7
350—400	17	4.8	4.8
400—450	11	6.3	6.2
450—500	5	7.6	7.8
500—550	0		
550—600	0		
600—650	1	6.7	
650—700	0		
700—750	0		

Here is shown a certain and gradual increase of redness with the increase of period, and other observers have found this law to be true. Variables of the other classes show a tendency to hold

to the same law, for short period ones of both types are nearly all of an intense white color. In a general way, then, the redness of a variable is a function of the length of the period, but what this relation is and why it exists has not been determined. It is a fact, however, that cannot be neglected in the formation of a theory to explain stellar variability.

SPECTRUM. Most of these variables have spectra that belong to Type III, stars of red color and strongly marked absorption bands. There has been but very little systematic work done in this direction, although it is a rich field for investigation in the study of variable star phenomena. My opportunities have not been such as to enable me to study this branch of the subject, and I shall therefore pass over it without discussion.

CAUSES OF VARIABILITY. In the foregoing discussion of the Length of Period, Variation of Period, Amount of Variation in Brightness, Form of Light Curve, Color and Spectrum, many peculiarities of this class of variables have been found, and in all respects there appears a lack of perfect uniformity.

The magnitude is variable, the period is variable, the amount of change is variable, the manner of change is variable, and even sometimes the color and spectrum are variable. The first test, then, for any theory advanced to explain this type of stellar variability is to see if under it the observed peculiarities would be possible. If they would not, then the theory may be dismissed without consideration. Numerous theories have been put forward to explain these phenomena, and I will now consider some of the most important ones.

ECLIPSE THEORY. This theory, that the diminution of light in a star is caused by the revolution of a satellite (usually dark) around the primary star in a plane passing through the earth, is the true one for the explanation of the cause of variability in short period stars of the *Algol* type. But it is plain to be seen that this theory will not explain the variability in stars of long period, for, under the conditions of this theory, the light of the star must remain constant for at least half the revolution of the satellite, or half the period of the star, and this is the case in no other stars except variables of the *Algol* type.

AXIAL ROTATION. It has been supposed that variable stars may be brighter upon one side than upon the other, and that, by

rotation, the bright and dark sides are alternately turned toward the earth.

This might explain a very small variation, but it is almost impossible to conceive of a star one side of which is two or three thousand times as bright as the other. Under such conditions, also, it would be natural to expect much more of uniformity than is actually observed. For instance, under this theory, it is impossible to explain the fact that the rise from minimum is quicker than the fall from maximum except by assuming highly improbable conditions. Again, too, it has been found recently that in a few of these stars bright lines appear in the spectra as the star approaches maximum, and this seems to indicate that the variability is associated closely with luminous changes in the stellar atmospheres. We may dismiss this theory, then, as entirely inadequate to explain the observed phenomena.

TIDE THEORY. Several German astronomers have attempted to explain the phenomena of variability through the tide influence of satellites. From the character of the spectra it is inferred that these variables possess highly absorptive atmospheres and the tide theory supposes that, as the satellite passes periastron, an immense atmospheric tide is produced, such as to largely increase the absorption and thus cause a diminution of brightness. Such a theory appears plausible enough, but I have been unable to determine how the light curves that are actually found could be produced in that manner. If we suppose the orbit of the satellite to be circular, or approximately so, and the plane of the orbit to pass through or near the earth, then with every revolution of the satellite the star would pass through two maxima and two minima with equal intervals between. But, as remarked before, it is almost an invariable rule that the interval from minimum to maximum is shorter than the interval from maximum to minimum.

It seems then that the observed phenomena cannot be explained on the supposition of a circular orbit. If, on the other hand, as is more likely to be the case, we assume the orbit to be eccentric, then the intervals would be unequal, but it would as often happen the interval from maximum to minimum would be shorter than the interval from minimum to maximum as *vice versa*. This appears to me to be a fatal objection to the tide theory, as a general explanation of the phenomena under consideration. The spectroscopic evidence, also, is no more favorable to the tide theory than to the axial rotation theory.

Spot Theory. It was long ago suggested that the variability of stars might be caused by disturbances similar to those occurring on the surface of the sun. There is a very marked resemblance between the curves of sunspot frequency and of long period variables. They are not only of the same general form, but they are marked by much the same kind of irregularities. Both are steeper in ascent than in descent; both show accelerated or retarded maxima and maxima of unequal intensities; both may show secondary maxima in the descent. In the curves representing these phenomena a maximum of spots on the sun corresponds to a maximum of light in the star and not *vice versa*, as might be supposed. As in some variables the apparition of bright lines has been detected at maximum, so in the sun the emissive intensity of the corona probably increases with the growth of spots. All these marked similarities lead one to infer common causes for the phenomena. There is one marked difference, however. In long period variables the mean change of brightness is about six magnitudes, while in the sun the change of brightness due to spots, tremendous as these disturbances are, could not possibly produce a change of more than a small fraction of a magnitude.

In respect to the spectra also there is a difference. The sun belongs to Type II, continuous spectra with narrow dark lines, while almost all the long period variables belong to Type III, red stars with strong and broad absorption bands. It is now generally believed that sunspots are caused by the downfall upon the sun's photosphere of cooled matter previously ejected, but it is almost impossible for us to conceive of a raining of matter on a star sufficiently great to produce a one or two thousand fold increase of brilliancy. This may be a true theory of stellar variability, but it cannot yet be accepted as such.

Collision Theory. Mr. Lockyer, in connection with his *Meteoritic Hypothesis*, has propounded a collision theory of stellar variability. The part of it that applies to the variables now under consideration is briefly as follows: These stars are not compact bodies like the earth or sun, but are swarms of meteorites, each attended by a satellite swarm revolving in a very eccentric orbit. The periastron distance is so small that when the satellite swarm reaches that part of its orbit the two bodies mingle to some extent, thus producing collisions and a consequent increase of light. As the satellite moves away from periastron the collisions become less numerous and the light of the star dies away. Thus the

minimum brightness is the normal state and the maximum abnormal. Different types of variation can be illustrated by the diagrams.

In Fig. IV the satellite goes through the midst of the primary and at apastron is entirely free from the primary, which would produce a faint minimum with a large range to maximum. In Fig. V the satellite does not pass through the central part of the primary, so that the range of brightness would not be so large. In Fig. VI the satellite is never free from the primary, so that the minimum would be bright and the range to maximum small. And so by variations in the densities of the swarms, in the eccentricity and length of the orbit, in the positions of periastron and apastron, it is possible to explain any observed range in brightness or length in period.

If the star has a secondary maximum it is but necessary to suppose two satellite swarms rather than one. Irregularities in the occurrence of maxima and minima are explained by the supposition that there are satellite swarms which do not enter the primary, or are always within it, but whose attraction is sufficient to accelerate or retard the satellite swarm that does enter the primary.

As before stated, it is an observed fact that the rise from minimum is considerably more rapid than the decline from maximum; this we at once see would be one of the necessary conditions of the collision theory.

Again, the brightness of a single star is not the same at every maximum, and this not only would be possible but highly probable under the collision theory. The spectra lend further support to this theory. The appearance of bright hydrogen lines and carbon flutings at the maxima of some of these stars indicates a real access of incandescence rather than a clearing away of atmospheric clouds or absorption vapors. The theory has the further advantage of explaining temporary stars in the same manner as variables of long period, and the spectra of these two classes are so much alike as almost to preclude the possibility of their being due to different causes. The recent discovery that the new star in *Auriga* was really composed of at least two bodies, lends further support to the collision theory.

Objections have been urged against this theory, the nature of which can be seen from the following quotation: *

* MISS CLERKE'S *System of the Stars*, page 124.

"But the objection inevitably arises that this state of things could not long subsist. Even if set on foot, it would prove transient. By mechanical necessity, the satellite-swarm should speedily become extended into a ring, with, of course, complete effacement of variability. Thus each maximum of a star like *Mira*, if produced in the way supposed, would be feebler and more prolonged than its predecessor, until maxima and minima were brought to the same uniform level."

Without doubt the continuance of collisions would *sometime* use up the satellite-swarm. But none of the variable stars have been known more than a few hundred years, and from what we know of the magnitude of sidereal bodies, and the time required for the evolution of the heavens, we are fully warranted in supposing that a few hundred years would make no perceptible difference in these stars. The other objection can be answered by an illustration from the solar system. The *Leonid* and *Andromede* meteors have been known much longer than any variable star, and they are as yet very far from being extended into rings.

The collision theory is the best one yet advanced to explain the observed phenomena. There are no serious objections to it as a theory, and any degree of regularity or irregularity can be explained by it without extravagant suppositions. It yet remains, however, to be proved that these stars are really meteoritic swarms, as Mr. LOCKYER states.

CONCLUSION. The *Eclipse Theory* is no longer advanced to explain the phenomena of long period variables.

The *Axial Rotation Theory* might explain a small variation in particular cases, but is entirely inadequate as a general explanation.

The *Tide Theory* is inconsistent with observed peculiarities, and hence cannot be accepted.

The *Spot Theory* may be a true one, but cannot yet be accepted as such.

The *Collision Theory* explains most satisfactorily the observed phenomena, but cannot be accepted as a true theory until further proof is furnished of the fundamental principles upon which it rests.

Investigations thus far have established the following facts: — That in the changes of variables of long period perfect uniformity is entirely lacking; that periods of about a year largely predom-

inate; that the rise from minimum is more rapid than the fall from maximum; that an unusual proportion of red stars are variable, and that nearly all variables of long period are red; that the redness increases with the length of the period; that the spectra of nearly all are marked with broad and strong absorption bands; that in a few bright hydrogen lines and carbon flütings appear in the spectrum as the star approaches maximum.

From these facts it is highly probable that the variations in brightness are produced by luminous changes in the stellar atmospheres, and that these changes are brought about in some way by the influence of planetary, meteoric or cometary attendants.

But the time has not yet come to formulate with certainty the causes of variability of stars in this class. A large amount of work, both of a spectroscopic and telescopic nature, must first be done in order to learn more of the physical constitution of these stars, and of the peculiar laws under which their variations take place.

My observations referred to in this paper were made with the 15.5-inch equatorial telescope of the Washburn Observatory, at Madison, Wisconsin, between November, 1889, and July, 1892.

OBSERVATIONS OF THE OCCULTATIONS OF *MARS* AND *JUPITER*.

1892, SEPTEMBER 3 AND SEPTEMBER 9.

BY PROFESSOR J. M. TAYLOR.

OBSERVATORY OF THE UNIVERSITY OF WASHINGTON,
SEATTLE, WASH., September 13, 1892.

I send you the result of my observations of the occultations of *Mars* and *Jupiter*. I had no means at hand to determine my watch correction, but set it carefully by a regulator keeping Pacific standard time.

SATURDAY, September 3, 1892.

Observation of the Occultation of Mars by the Moon.

Immersion..	First contact..	$9^h\ 27^m\ 15^s$.	P. S. time.
	Mars hidden..	$9^h\ 28^m\ 21^s$.	" "
Emersion...	First sight....	$10^h\ 25^m\ 26^s$.	P. S. time.
	Full view.....	$10^h\ 26^m\ 21^s$.	" "

FRIDAY, September 9, 1892.

Occultation of Jupiter by the Moon.

Watch keeping Pacific standard time. No allowance made for watch correction.

Three satellites precede the planet.

First satellite hidden . .	5^h 20^m	A. M.
Second " " . .	5^h 30^m	"
Third " " . .	5^h 31^m 45^s	"

Immersion . . { First contact of *Jupiter* and Moon . . 5^h 35^m.
{ *Jupiter* hidden . . . . 5^h 36^m 45^s.

While the planet was behind the moon I was called away and left the instrument in charge of a student, who did not succeed in making a record of the time of emersion.

The latitude of the Observatory is 47° 35′ 54″ North. The longitude is 122° 20′ 0″ West.

A LARGE SOUTHERN TELESCOPE.

By Prof. E. C. PICKERING,
Director of HARVARD COLLEGE OBSERVATORY.

The wide interest in astronomical research is well illustrated by the frequent gifts of large telescopes to astronomical observatories by wealthy donors who are not themselves professional students of astronomy. The number of these gifts is continually increasing, and in no department of science has greater liberality been displayed. Unfortunately, the wisdom shown in the selection of good locations for the telescopes has not equaled the generosity with which they have been given. Political or personal reasons, rather than the most favorable atmospheric conditions, have in almost all cases determined the site. These telescopes have been erected near the capitals of countries or near large universities, instead of in places where the meteorological conditions would permit the best results to be obtained. The very conditions of climate which render a country or city great are often those which are unfavorable to astronomical work. The climate of western Europe and of the eastern portion of the United States is not suited to good astronomical work, and yet these are the very

countries where nearly all the largest observatories of the world are situated. The great number of telescopes thus concentrated renders it extremely difficult for a new one to find a useful line of work. The donor may therefore be disappointed to find so small a return for his expenditure, and the opinion has become prevalent that we cannot expect much further progress in astronomy by means of instruments like those now in use. The imperfections of our atmosphere appear to limit our powers, and are more troublesome, relatively, with a large than with a small telescope. Accordingly it has not been the policy of the Harvard College Observatory to attempt to obtain a large telescope to be erected in Cambridge. In order to secure the greatest possible scientific return for its expenditures, large pieces of routine work have by preference been undertaken which could be done with smaller instruments. These conditions are now, however, changed. A station has been established by this Observatory near Arequipa, in Peru, at an altitude of more than eight thousand feet. During a large part of the year the sky of Arequipa is nearly cloudless. A telescope having an aperture of thirteen inches has been erected there, and has shown a remarkable degree of steadiness in the atmosphere. Night after night atmospheric conditions prevail, which occur only at rare intervals, if ever, in Cambridge. Several of the diffraction rings surrounding the brighter stars are visible, close doubles in which the components are much less than a second apart are readily separated, and powers can be constantly employed which are so high as to be almost useless in Cambridge. In many researches the gain is as great as if the aperture of the instrument was doubled. Another important advantage of this station is, that as it is sixteen degrees south of the equator, the southern stars are all visible. A few years ago a list was published of all the refracting telescopes having an aperture of 9.8 inches or more (*Sidereal Messenger*, 1884, p. 193). From this it appears that nearly all of the largest telescopes are north of latitude + 35°, although this region covers but little more than one-fifth of the entire surface of the earth. None of the seventeen largest and but one of the fifty-three largest telescopes are south of this region. Of the entire list of seventy-four, but four, having diameters of 15, 11, 10 and 10 inches, are south of +35°. The four largest telescopes north of + 35° have apertures of 36, 30, 29, and 27 inches respectively. But few telescopes of the largest size have been erected since this list was prepared, and the pro-

portion north and south is still about the same. It therefore appears that about one-quarter of the entire sky is either invisible to, or so low that it cannot be advantageously observed by, any large telescope. The Magellanic clouds, the great clusters in *Centaurus*, *Tucana* and *Dorado*, the variable star η *Argus*, and the dense portions of the Milky Way, in *Scorpius*, *Argo* and *Crux*, are included in this neglected region. Moreover, the planet *Mars* when nearest the earth is always far south. The study of the surface of this and of the other planets is greatly impeded by the unsteadiness of the air at most of the existing observatories. Even under the most favorable circumstances startling discoveries —relating, for example, to the existence of inhabitants in the planets—are not to be expected. Still it is believed that in no other way are we so likely to add to our knowledge of planetary detail as by the plan here proposed. The great aperture and focal length and the steadiness of the air will permit unusually high magnifying powers to be employed, and will give this instrument corresponding advantages in many directions,—for instance, in micrometric measures, especially of faint objects. It can be used equally for visual and photographic purposes; and in photographing clusters, small nebulæ, double stars, the moon, and the planets, it will have unequaled advantages.

A series of telescopes of the largest size (including four of the six largest, the telescopes of the Lick, Pulkowa, U. S. Naval, and McCormick Observatories) has been successfully constructed by the firm of ALVAN CLARK & SONS. But one member of the firm now survives, Mr. ALVAN G. CLARK; and he expresses a doubt whether he would be ready to undertake the construction of more than one large telescope in the future. The glass is obtained with difficulty, and often only after a delay of years. A pair of discs of excellent glass suitable for a telescope having an aperture of forty inches have been cast, and can now probably be purchased at cost, $16,000. The expense of grinding and mounting would be $92,000. A suitable building would cost at least $40,000. If the sum of $200,000 could be provided, it would permit the construction of this telescope, its erection in Peru, and the means of keeping it at work for several years. Subsequently, the other funds of this Observatory would secure its permanent employment. Since a station is already established by this Observatory in Peru, a great saving could be effected in supervision and similar expenses, which otherwise would render a much larger outlay necessary.

An opportunity is thus offered to a donor to have his name permanently attached to a refracting telescope, which, besides being the largest in the world, would be more favorably situated than almost any other, and would have a field of work comparatively new. The numerous gifts to this Observatory by residents of Boston and its vicinity prevent the request for a general subscription; but it is believed that if the matter is properly presented, some wealthy person may be found who would gladly make the requisite gift, in view of the strong probability that it will lead to a great advance in our knowledge of the heavenly bodies. Any one interested in this plan is invited to address the author of this article.

CAMBRIDGE, Mass., U. S. A., September, 1892.

ON THE RADIANT POINTS OF METEOR-SHOWERS.

By W. H. S. MONCK, F. R. A. S.

The earlier observers of meteor-showers usually regarded them as of considerable duration, without any material change in the radiant. It was not until the connexion of certain showers with comets was pointed out that a shorter duration was generally adopted as agreeing best with the mathematical theory of the subject. But practical observers can hardly be said to have ever adopted the short-duration theory, and Mr. DENNING began to impugn it openly not long after the theory of SCHIAPARELLI had been generally adopted. In this he was supported by the late Mr. R. P. GREG, who held, in spite of theory, that the average duration of a meteor-shower was at least three weeks. I am not aware that Mr. DENNING has anywhere expressed an opinion as to the average duration, or as to whether stationary or long-enduring showers constitute the rule or the exception, but he seems to have established the existence of many such showers extending considerably beyond Mr. GREG'S three weeks. The object of the present paper is to show that stationary and long-enduring radiants are the rule, not the exception, and that the mathematical theory of the subject must to a considerable extent be recast in order to account for them. I shall endeavor to show this by an analysis of the radiants comprised in the first quadrant

of Right Ascension in Mr. DENNING's great Catalogue of 918, or rather 920, radiants in the *Monthly Notices* of the R. A. S. for May, 1890. The order which I follow is that of Right Ascension, varied only to show the grouping round particular points. In giving the dates I include those contained in the column "Other Nights of Observation." In the column headed "Position of Radiant," the first figure represents the Right Ascension, and the second the Declination of the radiant point, the sign — being used to indicate South Declination. The list will, I think, be found complete as far as it goes.

Position of Radiant.	Date.
0°+53°	Aug. 8–14
1°+63°	Sept. 15
1°— 5°	Aug. 20–28
4°— 2°	Sept. 3–5
3°+27°	Aug. 7
4°+20°	Aug. 3–7
5°+17°	Aug. 21–23
5°+10°	July 27–Aug. 1
5°+10°	Aug. 23–25
5°+10°	Sept. 13–22
5°+11½°	Sept. 12–15
5°+12°	Aug. 21–24
5°+12°	Aug. 17–20
6°+11°	July 12–13
7°+10°	Sept. 22
7°+11°	July 31–Aug. 1
7°+11°	Aug. 2–10
3°+35°	July 26
4°+35°	July 7
5°+35°	July 11
5°+35°	July 16
5°+35°	Aug. 20–22
6°+34°	July 27
6°+35°	July 30
6°+37°	Aug. 10
7°+35°	Oct. 1–7
7°+36°	July 28
7°+37°	July 12
7°+37°	July 29
8°+33°	Aug. 8–14
8°+35°	Oct. 8–14
8°+38°	Aug. 12
10°+37°	Aug. 16
10°+38°	Aug. 12
13°+38°	Sept. 10–17
3°+49°	July 8–11
5°+52°	July 16
5°+52°	Nov. 10–13
5°+54°	Aug. 14–21
7°+51°	Oct. 15–20
7°+53°	July 17
8°+52°	July 26–30
8°+53°	Aug. 10–12
7°+44°	Sept. 13–24
8°+45°	Aug. 21–24
11°+47°	July 31–Aug. 1
11°+48°	July 11–14
10°± 0°	Sept. 12
11°+ 8°	Oct. 19–21
13°+ 6°	Oct. 11
13°+ 6°	Sept. 13–17
14°+12°	Sept. 22–30
12°+52°	July 25–30
14°+50°	Sept. 18–21
14°+50°	Oct. 13–15
16°+54°	Sept. 4–5
17°+53°	Nov. 7–18
19°+51°	July 19

Position of Radiant.	Date.
12°+70°	July 25–Aug. 1
16°+31°	July 22–Aug. 1
16°+31°	Aug. 19–24
16°+33°	Sept. 22–27
19°+30°	Nov. 5–10
18°+58°	July 28
20°+58°	May 30
20°+58°	Aug. 2–4
20°+56°	Sept. 13–22
21°+57°	July 20–Aug. 1
21°+55°	Oct. 14
18°+63°	July 19–24
18°+63°	Aug. 7–12
20°+65°	July 22–Aug. 1
20°+ 8°	July 30
20°+ 8°	Sept. 16
20°+14°	Sept. 19
21°+14°	Oct. 13–19
23°+17°	Oct. 5–7
21°+22°	July 28
21°+23°	July 5–6
21°+42½°	Nov. 30
22°+43½°	Nov. 28
22°+46°	Aug. 12–16
23°+41°	July 27–Aug. 1
24°+42°	Aug. 21–25
24°+44°	Nov. 27
24°+45°	Nov. 22–26
25°+42°	Aug. 19–21
25°+44°	Oct. 14–15
25°+46°	Nov. 4–7
26°+42°	Aug. 4–10
26°+44°	Nov. 26
28°+45°	Sept. 4–16
29°+46°	Nov. 27
30°+46°	Aug. 11–13
31°+49°	Aug. 6
23°+30°	Aug. 14–24
28°+28°	July 27–31

Position of Radiant.	Date.
28°+30°	July 11–13
23°+36°	Aug. 8–13
24°+36°	Oct. 14
25°+52°	July 22
25°+52°	July 23
27°+55°	July 28
29°+54°	July 27
30°+55°	July 28
31°+52°	Sept. 21–25
31°+54½°	July 29
32°+50°	Oct. 8
32°+50°	Aug. 14–23
32°+53°	July 27–28
32°+53°	July 28
32°+53°	July 30–Aug. 1
33°+54°	Sept. 6–9
33°+55°	Aug. 2
35°+54°	July 31
35°+54°	Aug. 2
36°+56°	Aug. 1
37°+57°	Aug. 4
25°+71°	Sept. 12–17
25°+71°	Sept. 30–Oct. 2
25°+71°	Oct. 4–8
26°+70°	Aug. 25
26°+72°	Aug. 21–30
26°+72°	Oct. 29–Nov. 7
27°+71°	Nov. 29–30
27°+71°	Nov. 28–Dec. 1
28°+70°	Dec. 9–10
28°+72°	Sept. 12–22
29°+72°	Oct. 11–21
32°+70°	Oct. 13–15
28°+36°	July 26–31
29°+37°	Nov. 4–10
30°+36°	Aug. 4–10
30°+36°	Sept. 14–15
30°+36°	Sept. 22–27
30°+36°	Sept. 21–25

Position of Radiant.	Date.
30°+36°	Oct. 5–8
30°+36½°	Aug. 25
31°+37°	Oct. 13–19
31°+37°	Nov. 30–Dec. 7
30°+16°	Nov. 4–7
31°+18°	July 30
31°+18°	Aug. 12
31°+18°	Oct. 7–8
31°+19°	Sept. 21–25
32°+17°	Aug. 2–4
32°+19°	Sept. 27–Oct. 2
34°+18°	July 27–31
34°+18°	Oct. 17–18
34°+19°	Sept. 20–24
38°+20°	Nov. 2–3
40°+20°	Oct. 12–24
31°+ 8°	Oct. 7
31°+ 9°	Oct. 14–15
32°+ 8°	Nov. 3
38°+12°	Oct. 14–25
40°+10°	Nov. 4–9
33°—20°	July 28
37°—13°	Nov. 28–Dec. 10
36°+47°	July 12
39°+28°	Aug. 18–21
40°+28°	Aug. 3–12
40°+29°	Oct. 11–15
40°+72°	Sept. 4–16
40°+77°	Oct. 31
40°+40°	Sept. 20
41°+38°	Sept. 17–19
41°+39°	Nov. 28–30
42°+38½°	Oct. 12–15
43°+39°	July 29–31
43°+39°	Aug. 23–25
43°+ 7°	Sept. 18–26
43°+ 5°	Oct. 22
45°+ 6°	Oct. 20
43°+21°	Oct. 31

Position of Radiant.	Date.
43°+23°	Nov. 1–7
46°+26°	July 22–31
46°+26°	Oct. 14–17
46°+23°	Sept. 7–9
46°+21°	Nov. 12–14
47°+28°	Oct. 8
48°+21°	Nov. 2–3
47°+16°	Oct. 7–8
49°+14°	Sept. 7–16
49°+31°	July 30–Aug. 2
50°+31°	Sept. 16–19
45°+46°	Oct. 15–20
46°+45°	Aug. 7–10
46°+44°	Aug. 19–21
46°+43°	Aug. 14–30
46°+47°	Aug. 21–23
47°+45°	Feb. 23–Mar. 12
47°+45°	July 20
47°+45°	Oct. 5–8
47°+45°	Sept. 15–16
47°+44°	Oct. 17–23
47°+44°	Dec. 28–Jan. 11
48°+42°	Nov. 27–Dec. 8
48°+43°	July 21–27
48°+43°	Aug. 2–10
48°+43°	Nov. 12–14
48°+43½°	Sept. 9–15
48°+44°	Aug. 19–21
48°+44°	Sept. 22–27
39°+55°	Aug. 2
40°+56°	June 14–25
40°+56°	Aug. 3
40°+56°	Aug. 7
40°+59°	Aug. 20–21
41°+55°	Aug. 7
41°+55°	Aug. 8
41°+58°	Aug. 7
42°+55°	Aug. 6
42°+55°	Oct. 6–16

Position of Radiant.	Date.
42°+57°	Aug. 5
42°+57°	Aug. 8
42½°+54°	Aug. 10
42½°+57½°	Aug. 10
43°+56°	Aug. 7
43°+56°	Aug. 8
43°+57°	Aug. 10
43°+58°	July 27–31
43°+58°	Aug. 10
43°+58°	Oct. 8–14
44°+55°	Aug. 9
44°+56°	Nov. 29
44°+56°	Dec. 1–10
44°+57°	Aug. 10
44°+58½°	Aug. 10
44°+59°	Aug. 10
44°+59°	Aug. 10
45°+57°	Aug. 10
45°+57½°	Aug. 11
45°+60°	Nov. 5–7
46°+57°	Aug. 11
46°+58°	Aug. 9–12
47°+57°	Aug. 11
48°+57°	Aug. 11
48°+57°	Aug. 12
49½°+57°½	Aug. 13
50°+55°	Aug. 12
50°+54°	Sept. 14
51°+58°	Aug. 13
52°+57°	Aug. 13
53°+57°	Aug. 14
47°+65°	Dec. 15–29
48°+63°	Sept. 6–7
48°+60°	Oct. 14
53°+64°	Sept. 5–7
54°+48°	Nov. 27
56°+52°	Oct. 5–8
60°+59°	Aug. 16
50°+75°	July 21–23

Position of Radiant.	Date.
50°+85°	Oct. 1–3
53°+71°	Nov. 16–18
54°+71°	Aug. 14–21
54°+71°	Oct. 5–6
54°+71°	Oct. 14–23
55°+71°	Sept. 15–24
55°+ 9°	Nov. 2–3
59°+ 9°	Sept. 15–16
62°+ 9°	Nov. 4
57°—12°	Jan. 4–8
57°+18°	Nov. 1–7
58°+16°	Nov. 7–8
58°+21°	Nov. 13–14
61°+18°	Oct. 21–29
59°+49°	Sept. 21–22
60°+48°	Aug. 10–16
60°+49°	Nov. 28–Dec. 10
60°+50°	Aug. 21–24
61°+48°	Aug. 16
61°+48°	Sept. 4–7
61°+48°	Sept. 15
61°+48°	Sept. 14–21
61°+48°	Nov. 13–14
61°+47°	Oct. 8–17
61°+49°	Sept. 5–7
61°+49°	Nov. 4–9
61°+50°	Aug. 21–23
60°+27°	Nov. 2–3
60°+28°	Aug. 21–23
60°+28°	Nov. 14–17
60°+29°	Sept. 8–14
61°+28°	Feb. 4–5
60°+34°	Nov. 3–5
60°+35°	Sept. 4–5
60°+37°	Nov. 27–Dec. 1
60°+38°	Sept. 7
61°+36°	Sept. 2–6
61°+36°	Sept. 15–16
61°+37°	Nov. 29–30

Position of Radiant.	Date.
$62°+34°$....	Nov. 12–14
$62°+35°$....	Aug. 21–25
$62°+36°$....	Aug. 28–Sept. 7
$62°+37°$....	Aug. 25
$62°+37°$....	Sept. 3
$62°+37°$....	Sept. 8–10
$62°+37°$....	Sept. 17
$62°+21\frac{1}{2}°$..	Nov. 12
$62°+22\frac{1}{2}°$..	Nov. 20
$63°+21°$....	Nov. 27
$63°+22°$....	Oct. 17
$63°+23°$....	Sept. 21–22
$64°+20°$....	Nov. 6–10
$64°+22°$....	Sept. 17–24
$64°+23°$....	Nov. 29–Dec. 1
$65°+24°$....	Nov. 14–23
$65°+60°$....	July 30–Aug. 1
$69°+51°$....	Aug. 6–10
$70°+50°$....	July 30–31
$70°+50°$....	Aug. 21-26
$71°+51°$....	Oct. 20
$69°+66°$....	Nov. 19–20
$69°+70°$....	Sept. 17–19
$70°+65°$....	Aug. 10–12
$70°+65°$....	Aug. 27–29
$70°+65°$....	Oct. 14–20
$70°+65°$....	Nov. 13
$70°+66°$....	Aug. 21–23
$70°+67°$....	Dec. 4–8
$71°+61°$....	Oct. 13–21
$70°+\ 4°$....	Sept. 14–25
$70°+15°$....	Nov. 27–29
$72°+14°$....	Jan. 2–8
$72°+14°$....	Sept. 9–19
$72°+14°$....	Sept. 15–16
$73°+14°$....	Sept. 7
$74°+14°$....	Oct. 8–16
$74°+15°$....	Aug. 29
$75°+15°$....	Sept. 13–22
$75°+15°$....	Sept. 27–Oct. 2
$75°+15°$....	Oct. 19–21
$72°+41°$....	Sept. 15–16
$73°+41°$....	Aug. 7–22
$73°+41°$....	Sept. 20–Oct. 2
$73°+42°$....	Nov. 14–15
$73°+43°$....	Sept. 12–15
$73°+45°$....	Sept. 22
$76°+44°$....	Sept. 21
$78°+43°$....	Nov. 20–28
$79°+49°$....	Dec. 8–13
$76°+56°$....	Sept. 21–25
$77°+57°$....	Sept. 15–17
$78°+57°$....	Oct. 14–15
$79°+56°$....	Nov. 15–17
$75°+31°$....	July 23
$75°+33°$....	Aug. 27
$76°+33°$....	Sept. 14–21
$76°+33°$....	Nov. 17
$76\frac{1}{2}°+33°$..	Nov. 12–13
$77°+31°$....	Oct. 8–16
$77°+32°$....	Nov. 7–9
$77°+32°$....	Dec. 22–29
$78°+24°$....	Nov. 27–28
$79°+21°$....	Nov. 22–26
$79°+24°$....	Dec. 4–7
$80°+21°$....	Oct. 8
$80°+23°$....	Dec. 4–8
$80°+24°$....	Nov. 12–14
$80°+24°$....	Dec. 15–28
$80°+25°$....	Sept. 20–25
$80°+25°$....	Nov. 29–Dec. 8
$81°+22°$....	Nov. 29–30
$82°+75°$....	Sept. 14–25
$84°+74°$....	Jan. 4–11
$85°+72°$....	Sept. 18–22
$84°-11°$....	Oct. 15–19
$84°+10°$....	Oct. 16–17
$85°+33°$....	Nov. 20

Position of Radiant.	Date.	Position of Radiant.	Date.
$87^\circ+34^\circ$	Sept. 13–18	$88^\circ+17^\circ$	Sept. 15–16
$87^\circ+35^\circ$	Sept. 27	$88^\circ+19^\circ$	Nv. 30–Dc. 10
$87^\circ+37^\circ$	Dec. 8	$(90^\circ+14\frac{1}{2}^\circ)$	(Oct. 20)
$87^\circ+42^\circ$	Sept. 25–26	$(90^\circ+15^\circ)$	(Oct. 17)
$87^\circ+42^\circ$	Oct. 11–16	$(90\frac{1}{2}^\circ+15\frac{1}{2}^\circ)$	(Oct. 19)
$87^\circ+43^\circ$	Sept. 21	$(91^\circ+15^\circ)$	(Oct. 22)
$84^\circ+55^\circ$	Oct. 5–8	$(91^\circ+16^\circ)$	(Oct. 16)
$85^\circ+53^\circ$	Nov. 20	$(91^\circ+16^\circ)$	(Oct. 24)
$87^\circ+56^\circ$	Sept. 17–19	$(91^\circ+17^\circ)$	(Oct. 11–14)
$(90^\circ+58^\circ)$	(Oct. 14–25)	$(92^\circ+14^\circ)$	(Oct. 17)
$(92^\circ+57^\circ)$	(Dec. 31)	$(92^\circ+14^\circ)$	(Oct. 21)
$87^\circ+20^\circ$	Sept. 9–19	$(92^\circ+15^\circ)$	(Oct. 17–18)
$88^\circ+17^\circ$	Oct. 17–19	$(93^\circ+17^\circ)$	(Oct. 15–20)

An analysis of the radiants in the remaining three quadrants of Right Ascension leads to similar results, and is only omitted because it would occupy too much space. It will be seen that nearly all the radiants observed by Mr. DENNING are reducible to a comparatively small number of certain or probable stationary or long-enduring radiants lasting, in almost all instances, more than the three weeks which Mr. GREG assigned as the average. At least twenty-five of these radiants appear to be distinctly indicated by the quadrant which I have examined. The comparatively small number of radiants which appear isolated were, in most cases, unfavorably situated for observation—as, for instance, when the radiant-point has a Southerly Declination, the observer being stationed at Bristol. The duration of the showers, it will be also noticed, is almost entirely included in the last six months of the year. The explanation of this fact is probably that radiants in this quadrant of Right Ascension are unfavorably situated for observation during the other six months, and it is very probable that the showers have in general a longer continuance, but have escaped observation for this reason. There are also instances in which showers which appear to be isolated in Mr. DENNING'S Catalogue are shown by the observations of others to have really a considerable duration. Thus, the position at $5^\circ+17^\circ$ on August 21–23 is rather too far removed from a well-known stationary radiant to be referred to it, but on reducing Italian observations Mr. DENNING obtained the same radiant

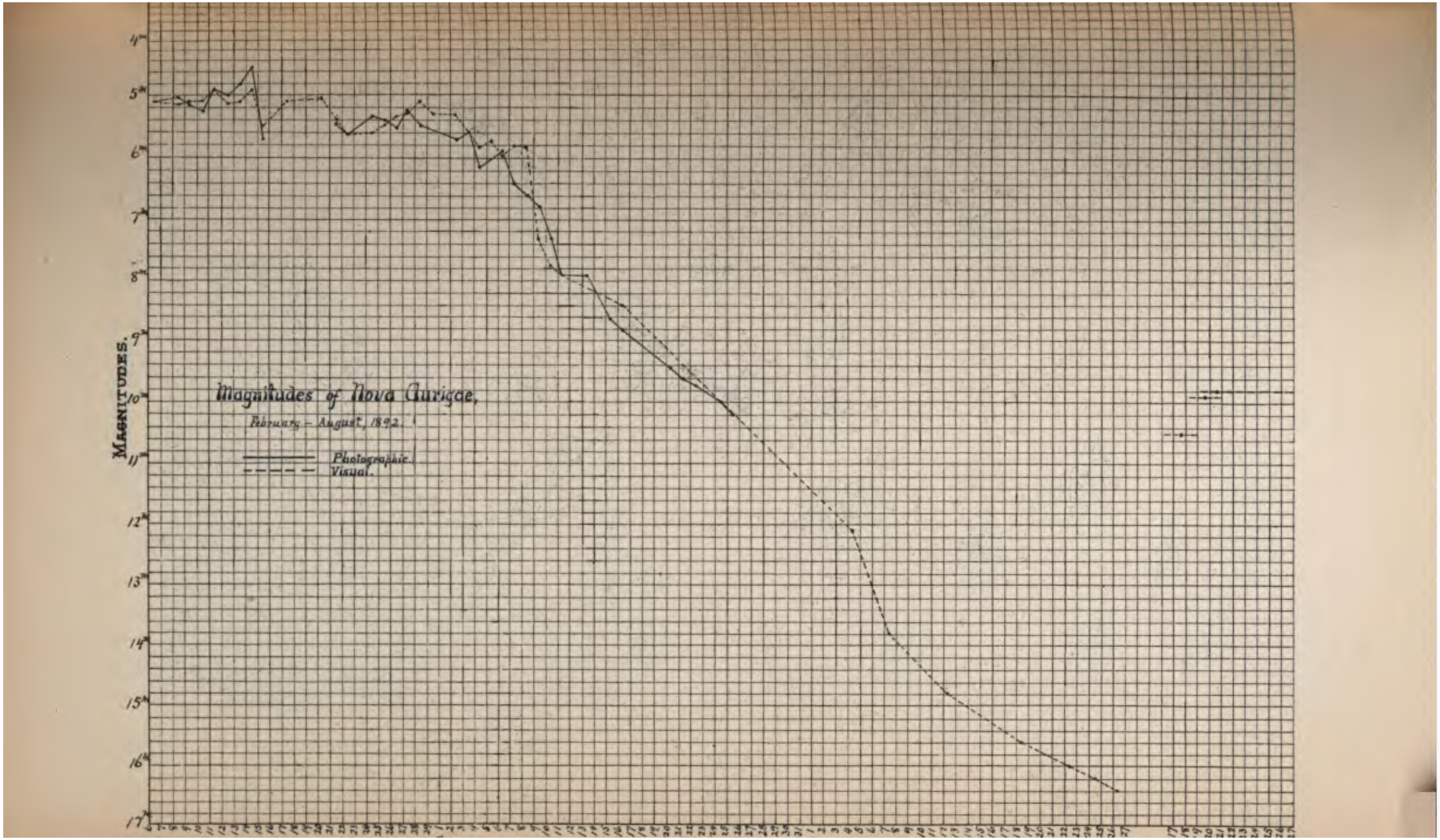
or the period May 26–June 13, and one at $5^\circ + 20^\circ$ for August 6–10 (corresponding with a radiant of $4^\circ + 20^\circ$ observed by himself), while SAWYER gives radiants at $2^\circ + 15^\circ$ and $2^\circ + 16^\circ$ for August 31–September 11, to which may be added radiants observed by HEIS, SCHMIDT and TUPMAN, giving a still longer duration to the shower. Again, it may be doubted, perhaps, whether the radiant at $3^\circ + 49^\circ$ on July 8–11 belongs to the same cluster as the next seven in my list, but SCHIAPARELLI observed meteors from the same radiant on July 31, and TUPMAN from $5^\circ + 49^\circ$ on August 20–29. Observations by others may also be in many cases called in to prove that Mr. DENNING'S showers are not intermittent, but continuous. There is, indeed, hardly any instance in which the duration of a meteor-shower can be shown to be a short one, or in which there is any appreciable shifting of the radiant as we pass from its earlier to its later manifestations; and I think the average duration of a shower amounts to at least double the period adopted by Mr. GREG.

SOLAR ECLIPSE, OCTOBER 20, 1892.

TIMES OF BEGINNING, ENDING, POSITION ANGLE, ETC., COMPUTED FOR SEATTLE AND SPOKANE, WASH., AND PORTLAND, OR.

By ORRIN E. HARMON, Chehalis, Lewis Co., Wash.

	Pacific Standard Time. A. M.		Local Time. A. M.		Duration.	Moon's Hourly Motion in Relative Orbit.	Position Angle North towards the East.		Magnitude of Eclipse Sun's Diameter = 1.
	Begins.	Ends.	Begins.	Ends.			At Begin'g.	At End'g.	
	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.		° ′ ″	° ′ ″	
SEATTLE. Lat. 47° 35′ N... Long. 8h. 9m. 20s. W.......	8 36 36	10 3 26	8 27 16	9 54 6	1 26 50	1300.6″	7 33 13	68 30 13	.13
SPOKANE. Lat. 47° 40′ N... Long. 7h. 49m. 40s. W.......	8 33 22	10 19 23	8 43 42	10 29 43	1 46 01	1262.9″	1 52 30	75 40 50	.19
PORTLAND. Lat. 45° 32′ N... Long. 8h. 10m. 52s. W......	8 45 11	9 55 10	8 34 19	9 44 18	1 9 59	1289.9″	14 48 46	62 34 52	.08



Magnitudes.
Magnitudes of Nova Aurigae,
February – August, 1892.
Photographic.
Visual.

VISUAL MAGNITUDES OF *NOVA AURIGÆ.*—OBSERVATIONS MADE AT MT. HAMILTON.

The visual magnitudes of *Nova Aurigæ* were carefully observed at Mt. Hamilton. The comparison stars employed were the following:

	D M.	α 1855.0	δ 1855.0	Mag.	Pickering's Star.
a	+32° 1024	5h 23m 18.4s	+32° 4.8′	5.0	*b*
b	+30 963	5 29 19.6	+30 23.9	5.6	
c	+30 898	5 17 51.4	+30 4.2	5.8	*e*
d	+29 909	5 20 27.9	+29 3.9	[7.0]	*g*
e	+29 911	5 20 52.4	+29 25.6	[7.5]	
f	+30 912	5 20 27.2	+30 28.4	[8.5]	*n*
g	+30 920	5 22 6.3	+30 35.1	[9.5]	
h		5 22 43.8	+30 21.1	[10.4]	*s*
i		5 22 50.9	+30 18.2	[10.6]	
j		5 22 44.2	+30 17.5	[11.8]	
k		5 22 42.8	+30 20.0	[14.8]	

The magnitudes of stars *a*, *b* and *c* are those of the *Harvard Photometry;* those of *d*, *e*, *f* and *g* are taken from the *Bonn Durchmusterung;* those of *h*, *i*, *j* and *k* are the estimates made by Mr. BURNHAM.* Accurate photometric determinations of the last eight magnitudes, enclosed in brackets, will probably change them considerably, and likewise the resulting magnitudes of the *Nova.*

At first each observer made only one estimate per night; but later, when it was noticed that the brightness sometimes fluctuated rapidly, two or more estimates were often made the same evening. The observations from February 6 to March 16 inclusive are given in the table below. The first column contains the Pacific standard times of observation. The second and fourth columns contain the comparisons of *Nova* with the other stars as made by observers J. M. SCHAEBERLE and W. W. CAMPBELL. The third and fifth columns give the resulting magnitudes of *Nova.* In the last column the estimates made with the eye and with the opera glasses are denoted respectively by E. and O. G.

* See *Monthly Notices R. A. S.* for April, 1892.

Pac. S. T.	J. M. S.	Mag.	W. W. C.	Mag.	Remarks.
1892	*Nova.*		*Nova.*		
Feb'y 6^d.417	$=$or$>a$	5.0±	$0.15<a$	5.15	E. and O. G.
8.375			$0.15<a$	5.15	E. and O. G.
9.437			$0.1<a$	5.1	E. and O. G.
10.396			$0.1<a$	5.1	E.
11.312	$0.1>a$	4.9	$0.1>a$	4.9	E.
12.458	$0.2<a$	5.2	$0.15<a$	5.15	E. and O. G.
13.458	$0.1<a$	5.1	$0.1<a$	5.1	E. and O. G.
14.312	$0.1>a$	4.9			E.
14.375			$0.1>a$	4.9	E.
15.292	$0.65<a$	5.65			E. and O. G.
15.312			$0.3<a$	5.3	O. G. "Fainter than ever seen before."
15.458			$0.05>b$	5.55	E. and O. G.
17.302			$0.25<a$	5.25	E.
17.437	$0.05<a$	5.05	$=a$	5.0	E. and O. G.
20.312	$=a$	5.0	$0.1<a$	5.1	O. G. Through thin fog.
21.333			$0.35<a$	5.35	E.
21.333			$0.2>b$	5.4	E.
21.555	$0.3<a$	5.3	$0.4<a$	5.4	E. and O. G.
21.555			$0.1>b$	5.5	E. and O. G.
22.333			$0.1<b$	5.7	O. G.
22.437	$0.05<b$	5.65	$0.05<b$	5.65	O. G.
24.302	$0.05<b$	5.65	$0.1<b$	5.7	O. G.
24.437	$0.05>b$	5.55	$=b$	5.6	O. G.
25.396	$0.1>b$	5.5	$0.1>b$	5.5	O. G.
25.521	$0.2>b$	5.4			O. G.
26.292	$0.15>b$	5.45	$=b$	5.6	O. G.
26.396	$0.25>b$	5.35	$0.2>b$	5.4	O. G.
26.542	$0.3>b$	5.3			O. G.
27.333			$0.3<a$	5.3	O. G.
27.333			$0.3>b$	5.3	O. G.
28.375	$0.05<a$	5.05	$0.15<a$	5.15	E. and O. G.
29.479	$0.25<a$	5.25	$0.3<a$	5.3	E. Clouds interfere.
March 2.364	$0.25<a$	5.25	$0.35<a$	5.35	E.
2.364			$0.25>b$	5.35	E.
3.532			$=b$	5.6	E. Clouds interfere.
4.302	$0.15<b$	5.75	$0.3<b$	5.9	O. G.
4.302			$0.1<c$	5.9	O. G.

Pac. S. T.	J. M. S.	Mag.	W. W. C.	Mag.	Remarks.
1892	*Nova.*		*Nova.*		
March 5.312	= *b*	5.6			O. G.
5.396			0.2 < *b*	5.8	O. G.
5.396			= *c*	5.8	O. G.
6.292	0.4 < *b*	6.0	0.3 < *b*	5.9	O. G.
6.292	0.05 > *d*		0.1 < *c*	5.9	O. G.
7.437	0.05 < *c*	5.85	= *c*	5.8	O. G.
8.312			0.05 < *c*	5.85	E.
9.333	0.3 < *d*	[7.3]	0.2 < *d*	[7.2]	O. G.
9.333	0.05 > *e*	[7.45]			O. G.
10.333	0.2 < *e*	[7.7]	0.3 < *e*	[7.8]	O. G.
11.333	0.3 < *e*	[7.8]			6-inch equatorial
11.333			0.45 < *e*	[7.95]	O. G.
16.396	0.1 > *f*	[8.4]	0.1 > *f*	[8.4]	6-inch equatorial

Thereafter the observations were made with the 36-inch telescope. In April *Nova* was compared with the stars *j* and *k*. The light interval between *j* and *k* was divided into ten grades, 10 at *j* and 0 at *k*, and the brightness of *Nova* estimated on that scale. Since the re-appearance of *Nova* in August the brightness has been compared in a similar manner with *g*, *h* and *i*. The observations are given below.

Pac. S. T.	*j*	*Nova.*	*k*	Observer.
1892—April $4^d.333$	10	10	0	J. M. S.
4.333	10	9	0	W. W. C.
4.361	10	8	0	E. S. H.
7.344	10	2	0	E. S. H.
7.344	10	1	0	J. M. S.
7.344	10	5	0	W. W. C.
12.364	10	1	0	E. S. H.
12.364	10	−1	0	J. M. S.
12.364	10	−1	0	W. W. C.
18.333	10	−1	0	E. S. H.
18.333	10	−3.5	0	J. M. S.
18.333	10	−3	0	W. W. C.
22.340	10	−6	0	E. S. H.
24.375	10	−7	0	W. W. C.
26.380	10	−9	0	E. S. H.

NOTES.

1892, April 4.—Seeing poor. *Nova* was suspected to be nebulous, though the image was too unsteady to decide, and the following notes were made:

"*Nova* is somewhat nebulous." E. S. H.

"*Nova* seems to be fuzzy at times. Is it in focus when the other stars are?" J. M. S., W. W. C.

1892, April 7.—Seeing good.

1892, April 12.—Sky hazy, but observations good.

1892, April 18.—Seeing good.

1892, April 22.—Seeing good.

1892, April 24.—Sky hazy, and observations only fair.

"*Nova* not seen all the time. Not brighter than ⅓*k*." E. S. H.

"*Nova* nearly on limit of vision." W. W. C.

1892, April 26.—Seeing good, but altitude of *Nova* is small.

"The estimate is extremely uncertain." E. S. H.

"Only an occasional glimpse of it. Probably two magnitudes greater than *k*." W. W. C.

Further attempts to observe *Nova* were prevented by a three weeks' storm, at the close of which the star was too near the sun to be observed. The rapid decline in brightness, however, indicated that it would pass beyond the power of the telescope in a few days after our last observation.

On August 17 we directed the telescope to the region of *Nova* to determine whether any trace of it remained, and were surprised to find its position occupied by a bright star. "Looking at *Nova* with powers 350 and 700, it is seen to lack the sharpness of the other stars of equal brightness. Moonlight interferes."

Dividing the light interval between the comparison stars *h* and *i* into ten grades, as before, the following estimates were made, with the eye-piece in the ordinary stellar focus:

Pac. S. T.	*h*	*Nova*	*i*	Observer.
1892, Aug. $17^{d}.630$	10	9	0	E. S. H.
17.630	10	9	0	J. M. S.
17.630	10	8	0	W. W. C.

According to these estimates *Nova* was about 10.5 magnitude.

When the eye-piece was focused on the *Nova*, Professor HOLDEN observed that *Nova* was slightly brighter than the star *h*.

The following estimates were made with the 12-inch telescope:

Pac. S. T.	*g*	*Nova*	*h*	Observer.
1892, Aug. $19^{d}.604$	10	5	0	W. W. C.
19.604	10	7	0	S. D. Townley.

According to these estimates the magnitude of *Nova* was about 9.8.

With the 4-inch finder of the great telescope Mr. CAMPBELL has compared *Nova* with the stars g and h on several mornings, with the practically constant result, $g = 10$, $Nova = 7$, $h = 0$.

In the accompanying illustration the visual magnitudes are represented by the system of points connected by the dotted lines. The times of observation are shown at the side of page, and the corresponding magnitudes at the end. The points should really be connected by a continuously curved line, instead of by a broken line; but to draw such a curve would require a practically continuous series of observations. The portion of the diagram corresponding to observations made after March 8 is only roughly approximate, since it is based upon merely provisional magnitudes of the last eight comparison stars; and, as stated before, these will probably be considerably changed by the photometric determinations. The estimates of *Nova's* magnitude made in August, recorded in the preceding paragraphs, are plotted near the right end of the diagram.

The points connected by the full lines represent the photographic magnitudes of *Nova* obtained by Professor SCHAEBERLE, the details of which are published in full in the *Astronomical Journal*, No. 269.

The magnitude of *Nova* since its re-appearance has been variously estimated, here and elsewhere, from 9.2 to 10.6. It is not improbable that some variation in brightness has occurred. But the different estimates made by different observers, and by the same observer with different instruments, are explained in part by the fact that the *Nova* is now a planetary nebula. Nearly all of its light falls in the spectrum at wave-lengths 5003 and 4954, and the apparent magnitude of an object with light peculiarly distributed is a function of the focusing and the color curve of the objective. In small telescopes the images of the nebula and of the comparison star are practically in focus at the same time. In the great telescope the focus for nebular rays is about 0.3 inch further from the object-glass than the stellar focus. While the ratio of

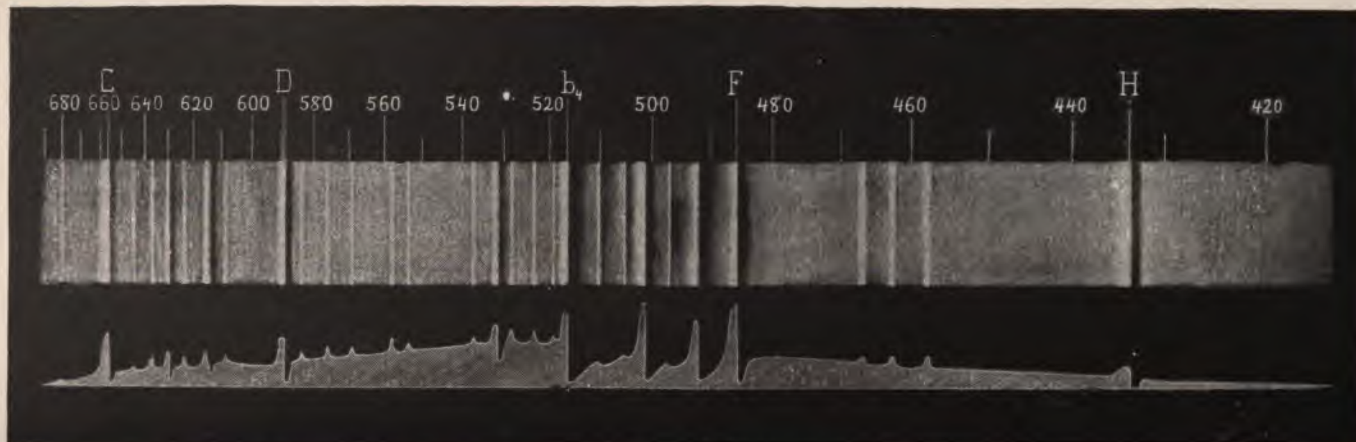
the light of the nebula to that of the star remains the same, yet with the eye-piece adjusted to the stellar focus the small nebula will, in general, appear relatively brighter in a small telescope than in a large one.

NOTE.—Observations of *Nova* were made abroad nearly a week before the telegraphic announcement of the discovery reached Mt. Hamilton. In order that our readers may have a record of the magnitudes beginning with the date of discovery, we append the observations made at Edinburgh by Dr. COPELAND, Astronomer Royal for Scotland, on the first six days of February:

Greenwich M. T.	Magnitude.
1892, Feb. 1^d 6^h	5.56
2 8	5.56
3 9	5.13
4 8	5.0
5 8.5	4.65
6 7	4.55

Fortunately, also, we have a fairly satisfactory record of *Nova's* magnitude before the date of its discovery. On December 8, 1892, Dr. WOLF, of Heidelberg, took a photograph of this region of the sky, which shows all the stars down to the 9th magnitude, but the *Nova* is not shown on this plate. Between December 10 and February 1 thirteen photographs of this region had been taken at the Harvard College Observatory for other purposes, on all of which the *Nova* is recorded. The list, as given by Professor PICKERING, is:

Date.	Magnitude of *Nova*.
1891, Dec. 10	5.37
11	5.33
13	5.22
17	4.67
18 } 18 }	4.46
28	4.55
30	4.60
1892, Jan. 5	4.58
8	4.72
9	4.67
16	4.96
20	5.23



VISIBLE SPECTRUM OF *NOVA AURIGÆ*, FEBRUARY 28, 1892.

(From *Astronomy and Astro-Physics* for November, 1892.)

It thus appears that the star became bright quite suddenly about December 9, and reached its maximum brightness the latter part of December, a full month before its discovery.

Addendum.—On November 19, using the 36-inch equatorial, Mr. CAMPBELL estimated that *Nova* was $0^m.3$ brighter than in August, comparisons at both dates having been made with the star *h*.

THE SPECTRUM OF *NOVA AURIGÆ.*

By W. W. CAMPBELL.

The discovery of a new star in the constellation *Auriga* has been the astronomical event of the year. Never before were all the available resources of so many observatories turned instantly from their various lines of work to the study of one object. The discoverer, Dr. THOMAS D. ANDERSON of Edinburgh, an amateur observer, with a small hand telescope magnifying ten times, observed the stranger several times in the last week of January, under the misapprehension that it was 26 *Aurigæ*. On the morning of January 31 he noticed that 26 *Aurigæ* was further east; and consulting a chart of that region the discovery was made that the star was "new." Thinking the star might be well known to astronomers, he at once wrote an *anonymous* postal card to the Astronomer Royal for Scotland, as follows: "*Nova in Auriga*, in Milky Way, about two degrees south of χ *Aurigæ*, preceding 26 *Aurigæ*." The discovery was verified by Dr. COPELAND on February 1, and the unique character of its spectrum was recognized. The discovery was immediately announced, telegraphically, and at nearly every observatory systematic observations of the star began at once.

The announcement of the discovery reached Mt. Hamilton February 6, and an outline of the different series of observations undertaken here was printed at that time in the *Publications*, pp. 84–85. The rapid decline of the star in brightness brought the observations to a close in March and April. But turning the great telescope upon the region occupied by *Nova*, on August 17, we were surprised to find it bright again, of the 10.5 magnitude, and thus began a new chapter in the history of this remarkable object. Both spectroscopic and visual observations

show that it is now a planetary nebula. [An account of this reappearance is given on p. 192 of the *Publications*.]

A series of observations of the magnitude of *Nova* after February 6 was secured here; and these, complemented by earlier observations secured elsewhere, will be found in the preceding paper on *Visual Magnitudes of Nova Aurigæ*. The present paper relates to spectroscopic observations made by me on seven nights between February 8 and March 13 inclusive, which will be treated under the heading of "The February and March Spectrum;" and to those made since August 17, which will be treated under the heading of "The Present Spectrum."

THE FEBRUARY AND MARCH SPECTRUM.

The observations, both visual and photographic, were made with the large BRASHEAR spectroscope and 36-inch equatorial. In the visual observations the 10½-inch view telescope and an eye-piece magnifying 13.3 times were used. The third and fourth orders of a grating of 14,438 lines to the inch were not found suitable for the study of this spectrum, principally on account of the strength of the continuous spectrum and the great breadth of lines. The Observatory did not then possess first and second order gratings, which could probably have been used to advantage. A dense thallium compound prism, dispersing 12° between B and H, was used on several evenings in fixing the positions and examining the character of the bright hydrogen lines, the D sodium lines, and a few other important lines. But an excellent 60° dense flint prism by BRASHEAR, dispersing 5½° between B and H, was for several reasons better adapted to a general determination of the wave-lengths, and was usually employed. With this prism the power of the spectroscope is such as easily to separate b_3 and b_4 in the solar spectrum, which are 1.6 tenth-metres apart.

In the photographic observations the eye-piece and micrometer were replaced by a camera-box suitable for holding a small plate-holder. No other changes were required to adapt the spectroscope to photography. In the winter I had decided to apply photography to spectroscopic work here; and, fortunately, on February 5 I had fitted the camera-box and determined the photographic focus. It is to be regretted that the Observatory did not then possess apparatus suitable for photographing the spectrum with greater dispersion than that given by the 60° prism.

THE VISIBLE SPECTRUM.

The general character of the visible spectrum is shown in the accompanying drawings of the spectrum and of the intensity curve, though in the former the contrast between the faint lines and the continuous spectrum was necessarily overdrawn. Many of the lines between D and F were so nearly masked by the continuous spectrum that under stronger dispersion they would have escaped detection entirely. The region between F and Hγ was seen to contain a large number of bright lines. A few of the more prominent ones were located on the first evening; but two photographs taken later on the same evening showed the lines in this region so satisfactorily that thereafter no effort was made to observe them visually. The drawing, therefore, really refers only to the portion of the spectrum below and including the F region, and is based upon the observations of February 8, 9 and 28. The intensity curve was drawn almost wholly from sketches made February 28, when the continuous spectrum had faded slightly, unmasking many of the lines previously invisible. On March 13, the continuous spectrum had in many regions wholly disappeared, and interfered with only a few of the measurements. A line at λ 5885, observed on the latter date only, is not shown in the drawing.

Altogether there were observed visually thirty bright lines, not counting a bright region at λ 432 and a faint line occasionally glimpsed near λ 680; and ten broad dark lines in contact with the more refrangible edges of ten of the strongest bright lines. Careful searches for lines below C were made, but only the trace of a line near λ 680 could be seen. In each of the ten dark lines, except that above Hγ, a background of continuous spectrum was still visible, and was so noted on several evenings. These lines were sharply defined below by the bright lines, but were diffuse above. They were from twelve to fourteen tenth-metres broad, and their centres were about eleven tenth-metres more refrangible than the most intense points in the corresponding bright lines. But the dark and bright lines evidently overlapped, and it is probable that their real centres were slightly less refrangible than their apparent centres. Possibly the real centres were near the fine bright lines shown in the photographs, which will be referred to later.

It was seen, first of all, that the normal positions for the hydro-

gen C, F and Hγ lines and the D sodium lines were occupied by bright lines. These and the lines λ 5168 and 5016 were carefully studied to obtain very accurately their positions and light curves. On the first few evenings all these lines were examined with the compound prism and extremely narrow slit, but no evidence of doubling was obtained; though with the exception of the D lines they were certainly very far from being uniformly bright throughout their breadth. The hydrogen lines C, F and Hγ, and the lines λ 5168, λ 5016 and λ 4923 were at least fifteen tenth-metres broad. Their more refrangible edges were quite sharply terminated. From the most intense points, which were about four tenth-metres below the upper edges, the intensity decreased about as shown in the drawing of the intensity curve, finally gradually merging into the continuous spectrum. The bright D line was about fifteen tenth-metres broad, quite sharply defined above, nearly uniform in brightness for ten or twelve tenth-metres, then merging gradually (but more sharply than the others) into the continuous spectrum below. The D line had greatly decreased in brightness by February 28; on March 13 it had apparently disappeared, and a faint line more refrangible than D was observed at λ 5885. The appearance of the spectrum at this point had changed considerably.

The points of maximum intensity in the C, F and Hγ bright lines were well enough defined to permit their wave-lengths to be determined within one tenth-metre, as was found by first setting the micrometer wire on the star lines and then throwing in the hydrogen comparison spectrum. These comparisons were made on several nights, and the star lines were found to coincide with the comparison lines within the limits stated above. I therefore adopted for the wave-lengths of these lines their usual values 6563, 4862 and 4341. On three nights the D star line and the D sodium lines of the spark spectrum and of the flame were carefully compared. With the compound prism and narrow slit the comparison lines were widely separated. When the micrometer wire was placed in contact with the upper edge of the star line it was also in contact with the upper edge of D_2. The comparison line D_1 appeared to fall in the exact centre of the broad star line, and I have accordingly adopted for it the wave-length 5896. The point of maximum brightness in the line λ 5168 was not well defined; but comparisons with magnesium b_4 showed that the wave-lengths were practically equal. The regions of maximum

brightness in the lines λ 5016 and λ 4923 were likewise quite broad, which made an accurate determination of their wave-lengths impossible.

Assuming the wave-lengths either of the comparison lines or of the star lines at λ 6563, λ 5896, λ 5168, λ 4862 and λ 4341, the wave-lengths of the intermediate lines were generally obtained from the readings of the large circle (12 inches in diameter, reading to 10″) corresponding to the different lines in the star, by interpolating between the assumed wave-lengths by means of curves based upon the solar spectrum. In some cases the wave-lengths could probably have been obtained more accurately by making micrometer comparisons, but usually the method employed was the most satisfactory for this spectrum. The wave-lengths resulting from the visual observations on five nights are given below. The appearance of a line depended upon its breadth, intensity, and position in the continuous spectrum, and it is impracticable to give a verbal description of the lines in this place. Reference can be made to the general intensity curve.

WAVE-LENGTHS OF BRIGHT LINES OBTAINED VISUALLY.

Feb. 8	Feb. 9	Feb. 22	Feb. 28	March 13	Means
....	....	...	[680]	...	[680]
6563	6563	6563	6563	6563	6563
6447	....	....	6456	....	6451
6363	6380	....	6367	6367	6369
6294	6299	....	6296	6295	6296
6251	6236	....	6234	...	6240
6151	6156	....	6158	...	6155
....	....	...	6087	...	6087
5896	5896	5896	5896	....	5896
....	....	....	...	5885	5885
....	....	....	5841	....	5841
....	...	....	5759	5763	5761
....	....	....	5690	....	5690
5585	5576	....	5575	5576	5578
....	....	...	5535	....	5535
5376	5372	....	5375	5390	5378
5320	5317	....	5321	5313	5318
5282	5282	....	5281	5274	5280
5229	5228	....	5237	5233	5232
5193	....	....	....	5193	5193
5167	5168	5168	5168	5168	5168
5103	5101	....	....	5103	5102
5056	....	...	..	5055	5055
5016	5013	5015	5016	5012	5014
4969	4972	....	4965	...	4969
4926	4922	....	4925	4921	4923
4862	4862	4862	4862	4862	4862
4670	....	....	....	....	4670
4629	...	....	....	....	4629
4583	4584	4582	....	....	4583
4341	4341	....	4341	4341	4341
....	....	....	[432]	....	[432]

THE PHOTOGRAPHIC SPECTRUM.

The 36-inch telescope is not suitable for a general study of the photographic portions of stellar spectra. Only a very limited region of a stellar spectrum can be photographed at one time to advantage, for the reason that the color curve of the 36-inch objective is very steep in the blue and violet, and only a few of the rays enter the slit. The focal length of the objective is 37mm. greater for the Hγ rays than for the F rays, and 34mm. greater for the Hδ than for the Hγ rays. For a given position of the spectroscope slit the rays of a certain wave-length come to a focus (a point) on the slit and pass through properly; those of greater wave-length are in focus before reaching the slit, and only a few of them pass through; those of smaller wave-length do not reach their focus, and only a few of them pass through the slit. Beyond Hδ the curve is so steep as practically to prevent the taking of photographs in this region. Another serious difficulty enters in this region of the spectrum: the image formed on the slit plate by the brighter visual rays is large and interferes very greatly with keeping the point in focus in the slit.

The photographs of *Nova Aurigæ's* spectrum were taken in two sections and with two sets of adjustments: first, with the slit in the focus for the F rays and the prism at minimum deviation for F; second, with the slit in the focus for the Hγ rays and the prism at minimum deviation for Hγ. In the first case the F rays proceeding from all parts of the object-glass entered the slit, while of the rays of greater or less wave-length only those proceeding from a region of the object-glass along and near the diameter parallel to the slit entered the slit at all. A similar result obtained for the Hγ setting. With ordinary dry plates the F photographs extend from the slightly actinic region λ 5200 to λ 4300, and are densest near and above F; and the Hγ photographs from λ 5000 to λ 4100 and densest in the Hγ region. One successful F photograph was obtained on an isochromatic plate, on February 14, which is measurable from λ 5686 to λ 4341. It is evident that the relative photographic brightness of lines in different parts of the spectrum cannot be obtained from these plates.

With the above limitations the photographs were successful from the first, and in all seven measurable negatives were obtained. A list of them is given below:

PHOTOGRAPHIC SPECTRUM OF *NOVA AURIGÆ*, FEBRUARY 9, 1892.

(From *Astronomy and Astro-Physics* for November.)

Date.		Region.	Slit Width.	Exposure.	Remarks.
1892, Feb.	8	F	0.0020 inch	15m	
	8	Hγ	0.0020	15m	
	9	F	0.0015	32m	
	9	Hγ	0.0015	26m	
	14	F	0.0011	37m	
Mar.	6	F	0.0010	120m	Very windy.
	6	Hγ	0.0010	150m	Very windy.

The spectrum of hydrogen was photographed on each plate for purposes of comparison, very near the stellar spectrum; on one side of it before beginning the exposure on the star and on the other side after closing the exposure. The original negatives were measured by means of a STACKPOLE measuring engine, and the measures were converted into wave-lengths by the aid of photographic interpolation curves. A list of the wave-lengths of bright lines obtained from each of the plates is given below. The results are corrected for the observer's motion and for curvature of the comparison lines. In a few cases it is impossible to determine from the negatives whether the lines measured were bright lines or were strong continuous spectrum between dark lines. In order to test the adjustments of the instrument, the lunar and hydrogen spectra were frequently photographed on the same plate, likewise the solar and hydrogen spectra, with the hydrogen tube both in front of the slit and at one side, and no displacement could be observed. A photograph of the spectrum of α *Orionis* showed the lines to be fine and sharp, while with the same adjustments and settings those of *Nova's* spectrum were broad and diffuse.

WAVE-LENGTHS OF BRIGHT LINES OBSERVED PHOTOGRAPHICALLY.

Feb. 8 F	Feb. 8 Hγ	Feb. 9 F	Feb. 9 Hγ	Feb. 14 F	Mar. 6 F	Mar. 6 Hγ	Means.	Remarks.
.....	.....	.....	.....	5685	.....	.....	5685	Maximum in broad line.
.....	.....	.....	.....	5630	.....	.....	5630	Maximum in broad line, poorly defined.
.....	.....	.....	.....	5584	.....	.....	5584	Two prominent lines, clearly separated.
.....	.....	.....	.....	5575	.....	.....	5575	
.....	.....	.....	.....	5534	.....	.....	5534	Maximum in broad line.
.....	.....	.....	.....	5454	.....	.....	5454	Maximum in broad line.
.....	.....	.....	.....	5379	.....	.....	5379	Maximum in broad line.
.....	.....	.....	.....	5329	.....	.....	5329	Double line very similar to F line.
.....	.....	.....	.....	5318	.....	.....	5318	
.....	.....	.....	.....	5285	.....	.....	5285	Prominent line, probably double, but not clearly separated.
.....	.....	.....	.....	5276	.....	.....	5276	
.....	.....	.....	.....	5234	.....	.....	5234	Very faint, poor.

Feb. 8 F	Feb. 8 Hγ	Feb. 9 F	Feb. 9 Hγ	Feb. 14 F	Mar. 6 F	Mar. 6 Hγ	Means.	Remarks.
......	......	......	......	5200	......	......	5200	Very faint, poor.
......	......	......	......	5176	......	......	5176 }	Similar to F line, double, but not clearly.
......	......	5170	......	5168	5170	......	5169 }	
......	......	......	......	5159	......	......	5159	Very faint companion to above.
......	......	......	......	5142	......	......	5142	Very faint line.
......	......	......	......	5095	......	......	5095	Faint line, poor.
5017	......	5019	......	5018	5018	......	5018	Similar to F line, no signs of doubling.
......	......	trace	......	5007	trace	......	5007	Companion to above.
4969	......	trace	......	4969	4969	......	4969	Faint, poorly defined.
......	......	......	......	......	4929.1	......	4929	Well defined March 6, equal to line below.
4922	......	4923	4923	4922.9	4921.7	4923	4923	Maximum of line resembling F line.
trace	......	trace	......	4913.2	4913.0	......	4913	Companion to above.
......	4871.3	......	4871.2	4868.9	4868.2	......	4869.9	Well defined March 6.
4861.7	4862.2	4861.4	4861.8	4861.1	4860.8	4862	4861.6	Principal F line.
4851.6	......	4851.8	4851.6	4852.0	4849.1	......	4851.2	Companion to above.
4777	......	4772	......	4773	......	......	4774	Estimated centre of very broad bright region.
4733	......	4739	......	4739	......	......	4737	Estimated centre of very broad bright region.
4700	......	4703	4715	4709	......	4710	4707	Estimated centre of broad bright region.
4671	......	4666	4672	4669	......	4668	4669	Centre of broad bright line.
4628	4632	4628	4631	4630	4631	4630	4630	Centre of broad bright line.
4588	4588	4587	4586	4587	4581	4585	4586	Centre of broad bright line.
4575	......	4576	4576	......	......	......	4576 }	Either well defined bright lines or continuous spectrum between absorption lines.
4570	......	4570	......	......	......	......	4570 }	
......	......	4564	4565	4564	......	......	4564 }	A group of lines, defined on fourth and fifth negatives, blended on the others.
4556	......	to	4559	......	......	4561	....	
to	4553		4554	4556	4554	to	4554 }	
4546	......	4547	4549	4549	......	4545	...	
4533	4533	4538	4524	4538	......	4528	....	
to	to	to	to	to	4516	to	4518	Appears like a group of lines, but not well defined.
4504	4504	4500	4509	4511	......	4504	....	
4490	......	4493	4494	......	......	4496	....	A group of lines not well separated, with maximum about λ 4481.
4483	......	to	to	4479	4480	to	4481	
4469	......	4478	4470	......	......	4469	....	
......	......	4455	......	......	......	......	....	
4446	......	to	4445	4444	......	4446	4445	A group of lines with maximum about λ 4445.
......	......	4441	......	......	......	......	....	
......	......	4436	4437	......	......	......	4436	Broad bright line.
4421	......	4420	4418	4418	......	4420	4419	Maximum of broad line.
4383	......	......	4386	......	......	4387	4385	Centre of bright region, apparently containing several lines.
......	......	4374	......	......	......	4376	4375	Rather broad line.
......	......	......	......	......	......	4355	4355	Apparently a third component of Hγ line.
......	4347.9	4348.0	4348.9	4347.9	......	4346.2	4347.8	Component of Hγ line, usually well defined.
4340.8	4340.2	4340.7	4341.5	4340.6	......	4340.1	4340.6	Principal Hγ line.
4332.1	4332.2	trace	4331.5	trace	......	4329.4	4331.3	Companion to above.
......	......	......	4316	......	......	......	4316	Broad, appears double.
......	4296	......	4297	......	......	......	4296	Broad, well defined.
......	4266	......	4269	......	......	......	4267	Centre of broad line.
......	......	......	4246	......	......	......	4246	Broad diffuse line.
......	4238	......	4234	......	......	......	4236	Broad bright line, resembles F and Hγ groups.
......	......	......	4227	......	......	......	4227	Faint companion to above.
......	......	......	4209	......	......	......	4209	Broad diffuse line.
......	......	......	4180	......	......	......	4180	Very bright line.
......	......	......	4166	......	......	......	4166	Broad defined line.
......	......	......	4126	......	......	......	4126	Broad defined line.
......	......	......	4108	......	......	......	4108	Component of Hδ.
......	......	......	4102	......	......	......	4102	Principal Hδ line.
......	......	......	4095	......	......	......	4095	Companion to Hδ.
......	......	......	4082	......	......	......	4082	Maximum of broad line.

An enlargement of the Hγ photograph of February 9 is shown in the plate. A few defects in the original negative, mostly in the region of F, have been made to appear as lines by the cylindrical lens used in enlarging.

IDENTIFICATION OF THE LINES.

It was early noted by Professor VOGEL and others that the half-dozen prominent lines in *Nova's* spectrum coincided with prominent lines in the spectrum of the solar chromosphere. The probability that any line would be observed is a function of its intensity and the frequency with which it occurs, and therefore of the product of these two quantities. In the following table I have arranged a list of chromosphere lines whose wave-lengths agree closely with those of the lines in *Nova's* spectrum, placing opposite them the name of the element from which they originate, and the product of F $\times$ I of their frequency and intensity. They are selected from Professor YOUNG'S catalogue of 273 chromosphere lines, as given in SCHEINER'S *Spectralanalyse.* A few of the identifications are doubtful and are enclosed in brackets [ ]. The faint and infrequent chromosphere lines are not inserted in the list. It appears that nearly all the prominent lines in *Nova Aurigæ's* spectrum are prominent lines in the chromosphere spectrum, and *vice versa.* In the last two columns of the table are given a few other probable identifications. Many of the lines left unidentified fall near prominent lines or groups of lines in the spectrum of iron; while practically all of the lines can be matched by lines in the spectra of those elements which are prominent in the chromosphere. As surmised by Professor YOUNG, in *Astronomy* and *Astro-Physics* for April, the lines λ 6296 and λ 5578 are near the auroral lines λ 6298 and λ 5571. Likewise, the lines λ 5378, λ 5232, λ 5196, λ 4630 and λ 4355 are near other auroral lines; but the presence of so many iron lines in the spectrum renders it probable that these also are iron lines.

Nova Aurigæ		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
[680]	....	....	....	....	....	....
6563	....	6563	10000	Hydrogen	....	....
6451	....	[6455]	60	....	6451	Calcium
6369	....	....	....	....	..	....
6296	....	....	....	....	6303–98	Iron
6240	....	[6247]	40	Iron	....	....
6155	....	....	....	....	6161–55	Sodium
6087	....	.	...	....	....	....
5896	....	{5896}	1500	Sodium	...	....
		{5890}	1500	Sodium	....	....
5885	....	[5876]	9000	Helium	....	....
5841	....	....	....	....	....	....
5761	....	....	....	....	....	....
5690	5685	....	....	....	5688–83	Sodium
....	5630	....	....	....	....	....

Nova Auriga		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
5578	{5584	....	....	....	5587	Iron
	5575}	....	.	....	5576–70	Iron
5535	5535	5535	600	Iron	....	....
....	5454	5456–47	80	Iron	....	... .
5378	5379	[5372]	30	Iron	....	....
5318	{5329	5317	4500	Iron, Cor.	....	....
	5318}	5317	4500	Iron, Cor.	....	....
5280	{5285	5285	200	Iron	....	....
	5276}	5276	450	Iron	....	....
5232	5234	5235	80	Iron, Mn.	.. .	....
5193	5200	5198	150	....	....	....
	{5176	5184–72	3250	Magnesium	....	....
5168	5169	5169–68	1800	Iron, Mg.	....	....
	5159}			....	....	....
....	5142	....	....	....	....	....
5102	5095	...	....	. ...	....	. ...
5055	trace	....	...	....	....	....
5014	{5018	{5019	450	Iron	....	....
	5007}	5016}	300	Titanium	....	....
4969	4969	...	...	....	....	....
	{4929	4924	480	Iron	....	....
4923	4923	...	....	.. ..	....	....
	4913}	4919	60	Iron	....	....
	{4869.9			....	....	....
4862	4861.6	4861.6	8000	Hydrogen	....	....
	4851.2}			....	....	....
....	4774	....	....	....	....	....
....	4737	....	....	....	...	....
....	4707	....	....	....	4705	Magnesium
4670	4669	....	....	....	4669–65	Sodium
4629	4630	4630	270	Iron	4629	Cerium
4583	4586	4584	90	Iron	...	.. ..
....	4576	....	....	....	[4573]	Cerium
....	....	....	..	....	[4572]	Titanium
....	4570	....	....	....	[4571]	Magnesium
....	4564	4566	30	Iron	....	....
...	...	4564	50	Titanium	....	....
....	4559	4560	16	Iron	....	....
....	...	4556	50	Iron	....	. ...
....	4554	4554	50	Barium	....	....
....	4549	4550	80	Iron	....	....
....	{4534	4534	25	Iron	....	....
...	to			....	....	....
....	4502}	4502	90	Titanium	....	....
....	{4490	4492	160	Manganese	....	. ...
....		4490	45	Iron	...	....
....	4481	4482	10	Iron	4481	Magnesium
....		4472	2500	Cerium	....	....
....	4471}	4470	100	Iron	...	....
....	4445	4444	20	Iron	....	....
....	4436	....	....	....	4435	Calcium
....	4419	....	....	....	....	....
....	4385	4385	16	Ca., Ce.	....	....
....	4375	4376–75	39	Iron	...	....
....	4355	....	....	....	4354	Calcium
	{4347.8			....	....	....
4341	4340.6	4340 7	6500	Hydrogen	....	....
	4331.3}			....	..	....
[432]	4316	....	....	. ...	4318	Calcium
....	4296	....	....	....	....	....
....	4267	....	...	....	....	....
....	4246	4246	90	Iron	....	....
....	{4236	4236	150	Iron	....	....
....	4227}			....	[4227]	Calcium
....	4209	[4216]	180	Calcium	. ..	....
....	4180	...	....	....	...	... .
....	4166	...	....	.. ..	4167	Magnesium
....	4126	....	....	....	....	....
	{4108			....	....	....
....	4102	4102	5000	Hydrogen	....	....
	4095}			....	....	....
....	4082	4078	50	Calcium	....	....

Near the centres of all the broad absorption lines shown on the photographs were comparatively fine bright lines. They were measurable at λ 5159, λ 5007, λ 4913, λ 4851 and λ 4431. They probably existed also at λ 6552, λ 6285, λ 5885 and λ 5307, since it was noted that the continuous spectrum showed faintly in the emission lines at those places, which effect was probably due more to the presence of the fine lines than to the very much fainter continuous spectrum shown in a few of the photographs.

If they existed on the more refrangible sides of other prominent bright lines, they were either concealed by the strong continuous spectrum, or, in certain regions, confused with other lines. We can probably say they existed in all the broad absorption lines, but we cannot say whether or not they existed quite independently of the absorption lines.

CONCLUSIONS.

It has generally been conceded that *Nova Aurigæ* was a system of at least two bodies, one giving rise to the system of very bright lines, the other to the system of broad absorption lines. On several photographs a very faint continuous spectrum showed as a background in the absorption lines. This probably belonged to the bright line spectrum or spectra. The strong continuous spectrum which masked many of the fainter bright lines probably belonged to the dark line spectrum. Nearly all the photographs show the F and Hγ bright lines to be double, with different degrees of clearness. There are signs of doubling in the strong lines in the green, and on the F negative of March 6 the line λ 4923 is distinctly separated into two nearly equal components.

Professor VOGEL has accounted for the observed phenomena in this manner: the fine bright lines within the broad absorption lines were due to reversals such as are sometimes observed in the spectra of Sun-spots, and were caused by eruptions of gases from the interior of the body furnishing the dark line spectrum; the doubling of the bright lines was due to the presence of two bodies possessing bright line spectra; and therefore *Nova* was a system of three bodies moving with very different velocities in the line of sight.

Dr. and Mrs. HUGGINS have suggested a further simplification, and have ingeniously explained the apparent doubling and great breadth of the bright lines by combining the reversion theory of ZÖLLNER and VOGEL with the tidal theory of

KLINKERFUES and WILSING. They consider *Nova* as a system of two bodies, one yielding a bright line spectrum and the other a dark line spectrum.*

The re-appearance of *Nova* as a planetary nebula, apparently with only one system of lines, favors a simple origin. But the fact that the present system of lines does not coincide with any one of the four former systems either makes the original spectrum more complex, or it shows conclusively that orbital motion has ensued. In the latter case much light must be thrown upon the question by continued observation of *Nova's* velocity, and considerable time may be required.

While the hypothesis of two bodies quite generally satisfies the observations, and has the further very great advantage of simplicity, there are a few not unimportant points furnished by the photographs which favor the existence of three or four bodies: two or three yielding bright line spectra and one a dark line spectrum. These points are:

First—The two components of the bright lines are much more clearly defined in the later photographs than in the earlier. This was partly but not wholly due to the decline of the continuous spectrum. The photographs taken early in February show the broad bright lines F and λ 4923 to be double only with difficulty. Two condensations, the more refrangible one being the stronger, show certainly, but not clearly. The F photograph of March 6 shows these lines as well defined doubles. In the line λ 4923 the two components are separated too widely to present the appearance of reversion, and the continuous spectrum shows only very thinly in that region.

Second—In all the double lines shown on the March 6 photographs the two components are nearly equal, while in the earlier photographs the more refrangible components were the stronger.

Third—There is some reason to believe that the intervals between the components were less in March than in February, though on the earlier negatives the measures were subject to considerable uncertainty, and photographs taken elsewhere do not seem to show this variation.

Fourth—The normal position of the fainter lines throughout the spectrum (as compared with the chromosphere spectrum) is

* See *Astronomy and Astro-Physics* for August, 1892.

evidence that they were mostly associated with the more refrangible components of the double lines, ***and not with the double lines as a whole.***

Fifth—The fine bright lines appeared not only in the dark F and Hγ lines, but also in three dark lines in the green, all apparently in the same position relative to the principal series of bright lines.

Sixth—During the decline of *Nova* in brightness the continuous spectrum belonging mostly to the dark line star decreased more rapidly than the bright lines, while the fine bright lines decreased certainly no more rapidly than the principal bright lines.

The above evidence is far from conclusive, and is inserted now merely for completeness. On the hypothesis of four bodies, the principal system of bright lines was not displaced appreciably, and the star yielding it was practically at rest with reference to the solar system. Another system was displaced towards the red a distance corresponding to a velocity of recession of about 315 miles per second. The system of fine bright lines and likewise the system of dark lines were displaced towards the violet, a distance corresponding to a velocity of approach of about 400 miles per second.

THE PRESENT SPECTRUM.

The new star was clearly seen with the 36-inch telescope on April 24, when it was of the sixteenth magnitude or fainter. It was occasionally glimpsed late in the evening of April 26, when its altitude was small. Further observations were prevented by a three weeks' storm, at the close of which the star was too low in the west to be observed. The rapid decline in brightness made it probable that it would soon disappear from sight. But it was again observed by Professors HOLDEN and SCHAEBERLE and myself on August 17, when its magnitude was estimated 10.5. All the observers agreed that its appearance was different from that of other stars of the same magnitude, in that its disk was larger and its light duller. However, the moon was only a few degrees east of the star and the bright sky interfered with further observations on that point. A direct vision spectroscope of very small dispersion showed its spectrum to consist of three bright lines on a faint and continuous spectrum. The instrument did

not permit of measures being made to determine the wave-lengths, and the telescope was not available again for spectroscopy for several days. On August 19 (15 hours), with a more powerful spectroscope attached to the 12-inch telescope, the brightest line previously observed was resolved into three lines. These were at once recognized to be the three characteristic nebular lines, and thus the nebulous character of the object was established. By bringing lines into contact with a bar in the focus of the eye-piece and turning to *β Tauri* and *Venus* the wave-lengths were estimated to be 501, 496 and 486. The faint continuous spectrum was just visible.

The same morning Professor BARNARD, using the 36-inch telescope, observed the *Nova* as a nebula 3″ in diameter, with a tenth magnitude star in its centre. Thus, the nebulous character of the object was established independently by the two different methods.*

Further study of the spectrum with the large spectroscope has shown eighteen bright lines and a continuous spectrum corresponding to a star of the eleventh magnitude or fainter.

A table of the wave-lengths of the lines and their relative intensities is given below. The wave-lengths are reduced to the sun. The unmarked wave-lengths were obtained with the dense 60° flint prism and the 10½-inch observing telescope, using a magnifying power of 13.3. In obtaining those marked with an asterisk (*) the prism was replaced by a second order grating of 14,438 lines to the inch. In obtaining those marked thus (†) a first order grating was used. The one marked thus (‡) was obtained with a thallium compound prism. Those marked thus (§) were obtained photographically, using the 60° prism and replacing the the micrometer by a camera.

The photographs of October 12 and October 19 were obtained with a comparatively wide slit, and the wave-lengths are accurate to three places.

* See also page 228 of the present number, under the dates April 4 and August 17.

Intensity	Aug. 20	Aug. 21	Aug. 22	Aug. 23	Aug. 30	Sept. 3	Sept. 4	Sept. 6	Sept. 7	Sept. 15	Sept. 22	Oct. 12	Oct. 19	Nov. 2	Nov. 3	Nov. 9	Nov. 16	Nov. 17	Nov. 24
1	5746	5751	5750	5750	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.2	.....	.....	.....	.....	557]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.3	.....	5268	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	5003 6	5003.7	5003.7	*5003 1	5002 9 ‡5002.3 *5002.24	5002.4	†5001.97 *5001 80 §5001 9	§5001.9 §5002.4	†5001 83 *5002.00 §5002	†5002 54 *5002 05 §5002.1	‡5002 34 †5002.39 *5002.70	†5003 67 *5003.57 §5003	†5002.8 †5004.3 *5004.3 § 500	‡5004 49 †5004 32 *5004.34	‡5004 61 †5005.01 *5004 39	†5004 32 *5004.54	†5004.86 *5004.94	†5005.07 *5004.72	*5004.49 .....
3	4954	4953	4954	.....	.....	.....	§4953.3	§4953 3 §4952 1	§4953	§4954	.....	§4954	§ 495	.....	.....	.....	.....	.....	.....
1	486	4858 4	4858.3	.....	4857.3	4856.8	§4856 7	§4856.7	.....	§4857	.....	§ 486	§ 486	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 471	§ 471	.....	.....	.....	.....	.....	.....
0.4	4677	4684	4685	.....	.....	.....	.....	§4678	4680 §4685	.....	.....	§ 468	§ 468	.....	.....	.....	.....	.....	.....
0.7	4628	4633	4631	.....	.....	.....	.....	.....	4628 §4634	.....	.....	§ 464	§ 464	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 460	§ 460	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 451	§ 451	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	§4466	.....	.....	§ 447	§ 447	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 438	§ 438	.....	.....	.....	.....	.....	.....
0.8	436	4357.1	4358 9	4358.0	.....	4358.9	.....	.....	§4360	§4358 4	.....	§ 436	§ 436	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	§4335.9	§4335.8	.....	§ 434	§ 434	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 426	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 423	.....	.....	.....	.....	.....	.....
0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 410	.....	.....	.....	.....	.....	.....

The spectrum is that of a planetary nebula, but there are a number of peculiarities which may prove to be significant. Nearly all the lines have been found to exist either in the spectrum of the planetary nebula Σ 6, or in that of the *Orion* nebula; the lines in *Nova's* spectrum being displaced four or five tenth-metres toward the violet (during August and September). The light, therefore, emanates from *one source*, which has been approaching the solar system with great velocity. It has not been possible to determine the velocity with great accuracy on account of the great breadth and diffuse character of the lines. With the second order grating and narrow slit, the line at λ 5003 is at least eight tenth-metres broad and the edges very diffuse.

There is no line at or near D_3, nor at C, within the reach of this telescope. The strong line in the yellow at λ 5750 has not yet been found in any other spectrum. It falls about midway between the bright lines in the WOLF–RAYET stars, which recent measures made here place at about λ 5813 and λ 5692. The lines at λ 5003, λ 4954, λ 4858 (Hβ), λ 4336 (Hγ) and λ 410 (Hδ) are the well-known lines common to all the nebulæ. The lines at λ 4682 shows the proper displacement when compared with the broad line λ 4687 in the nebulæ Σ 6, N. G. C., 7027 and N. G. C. 7662, and the bright blue band in one class of the WOLF–RAYET stars. The faint line λ 4466 is undoubtedly identical with the strong line λ 4472 in Σ 6 and the *Orion* nebula. This line is probably identical with the ever-present solar chromosphere line λ 4472. By far the brightest line shown on the photographs is that at λ 4359. It is about eight or ten times as intense as the Hγ line at λ 4336. This line exists in the three other nebulæ which I have thus far examined for it. In Σ 6 its wave-length obtained from two negatives is 4363, and its intensity is about one-tenth that of the Hγ line. In N. G. C. 7027 its wave-length from two negatives is 4363 and its intensity is about one-fourth that of Hγ. In a photograph of the spectrum of the *Orion* nebula (showing about 25 lines between λ 5007 and λ 3800) this line is shown at λ 4364, and its intensity is about one-twentieth of that Hγ. Two negatives of the spectrum of Σ 6 show a line at about λ 4636. Similarly, as stated above, nearly all the lines in *Nova's* spectrum are found in the spectrum of the nebulæ.

The relation of the present spectrum to the early one of February and March is not apparent. It is possible that the present lines with their present wave-lengths might have existed in the early

spectrum and have escaped detection; but such an hypothesis adds to the complexity of the original spectrum, and is, therefore, unsatisfactory. It is more probable that the present lines correspond to one of the former systems of bright lines, and that orbital motion has ensued, thereby changing the wave-lengths. The presence of the very bright line in the early spectrum at λ 5016 practically precludes a correspondence with any but the least refrangible series of bright lines. Such a correspondence is rendered more probable by the presence in the early spectrum of lines at λ 5885 (D_3 displaced?) and at λ 4969 (second nebular line displaced?).

The series of observations made upon the chief nebular line seem to show that the velocity of approach toward the Sun was increasing in August, was practically constant during the first half of September and since then has been decreasing. The table below contains the wave-lengths of the chief nebular line resulting from the several nights' observations together with the corresponding velocities of approach in miles per second:

Date.		λ	Velocity.
1892, Aug.	20	5003.6	—128
	21	3.7	125
	22	3.7	125
	23	3.1	147
	30	2.4	173
Sept.	3	2.4	173
	4	1.9	192
	6	2.1	184
	7	1.9	192
	15	2.2	180
	22	2.5	169
Oct.	12	3.6	128
	19	3.8	121
Nov.	2	4.4	99
	3	4.7	87
	9	4.4	99
	16	4.9	80
	17	4.9	80
	24	4.5	—95

There does not appear to have been much change during November; but of the reality of the change of nearly one hundred miles per second since September 6th, I have no doubt. It is probably the result of orbital motion, though no definite statement is now justified concerning the nature of the orbit.

COMETS OF 1892 AND THEIR SPECTRA.

By W. W. Campbell.

Discoveries of comets have been announced in quick succession the present year, eight having been found since March 7. Seven of these are now observable in one night with telescopic aid, which is very unusual. A list of them follows:

a. Discovered by Swift, March 7, in Rochester, N. Y. At discovery it was visible to the unassisted eye, and during April was a beautiful naked-eye object. When at its brightest, the tail was visible for 12° or 15° from the nucleus. It was observed spectroscopically on nine mornings in April, May and June. Its spectrum was of the usual type, continuous for the nucleus and banded for the coma and the tail. Accurate measures* and drawings of the less refrangible edge of the green band showed that interesting changes were taking place at that point. On several mornings the band was terminated by bright lines, but on other and intermediate mornings the bright lines were not present. The wave-lengths of the lines were 5170, 5164 and 5157; the smaller wave-lengths corresponding to greater distances from the Sun.

Another observation was made November 17. The spectrum was continuous, but was faint. A faint tail extended in the direction $p=250° \pm$, but its spectrum was not strong enough to be seen. It will be seen that the apparent direction of the tail was not away from the Sun, but the anomaly can doubtless be explained as an effect due to the comet's position and distance. The comet is at present in *Andromeda.*

c. Winnecke's Periodic Comet, discovered at Vienna, March 18. It is not now visible in small telescopes, and has not been bright enough for observations of its spectrum.

b. Discovered by Denning, March 18, in England. It is a very faint comet, and now difficult to observe. Its spectrum has not been observable.

d. Discovered by Brooks, August 28, at Geneva, N. Y. It is an easy object for small telescopes, growing rapidly brighter, but will soon be inaccessible in the southeast. Its spectrum is of

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* Published in detail in *Astronomy and Astro-Physics* for October, 1892. The work on *Mars* interfered with the observations of this comet.

the usual type, continuous for the nucleus, and the yellow, green and blue bands for the coma and tail. The wave-lengths of the less refrangible edges of the bands were 561, 5152, and 472 on November 17.

e. Discovered by BARNARD, October 12, at Mt. Hamilton, with the CROCKER photographic telescope. It is probably a periodic comet of short period, and is now extremely faint. Its spectrum has been too faint to observe.

f. Discovered by HOLMES, November 6, in England. This is one of the most interesting comets of recent years. When discovered, about 2° southeast of the *Andromeda* nebula, it was easily visible to the naked eye. In the finder of the large spectroscope, magnifying about 700 diameters, it was seen on November 8 and 9 to be so sharply defined, rounded and dense that it seemed more like an immense planetary nebula than a comet.

The ordinary comet must be examined under low magnifying power, but this object easily bore a magnification of 700 times, and the structure of it was seen to good advantage. Near the center of the circular coma (5′.5 in diameter) was the usual nucleus, slightly elongated. Diverging from this, in a direction opposite to the Sun, was a quite dense fan-like structure which could be traced up to the edge of the coma, and even beyond the edge when the bright coma was just outside the field of view. This structure was the tail of the comet in embryo, which has since increased considerably in length. The apparent size of the comet has continually increased, until now its diameter is three or four times as great as when discovered.

Computers agree that it is not the lost BIELA comet, as was suspected at first, and that it is neither close to nor approaching the Earth. Its orbit is an ellipse, which seems to lie entirely outside the orbit of *Mars*.

The spectrum of the nucleus of an ordinary comet is continuous, showing that it, like the planets, is shining by virtue of reflected sunlight; while the spectrum of the coma and tail consists almost wholly of three or four bright bands which are sensibly identical with those given by the blue part of the ordinary gas or candle light. This part of the light is probably inherent in the comet.

The spectrum of HOLMES' comet is unique. All parts of it give a continuous spectrum; but, underlying this, there is cer-

tainly a trace of the green band. Photographs of the spectrum also show it to be continuous, but the wide slit employed leaves it in doubt whether FRAUNHOFER (dark) lines were present or not.

It is a remarkable coincidence that a bright comet should be observed near the radiant point of the BIELAN meteors, and that it should grow larger nearly at the time they were expected, and yet lie beyond the orbit of *Mars*, receding both from the Sun and from the Earth.

g. Discovered by BROOKS, Nov. 19, at Geneva, N. Y. No spectroscopic observations yet secured.

1892, November 28.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.*

GEORGE E. HALE, Director.

Through the munificence of CHARLES T. YERKES of Chicago, the University of Chicago is to have an astronomical observatory of the first class. Indeed, it is Mr. YERKES' express desire that in every particular the new observatory shall as nearly as possible attain the existing ideas of perfection. No definite limit has as yet been assigned to the expenditure contemplated, but the generosity of the donor is fully indicated by his wish that the completed observatory shall be second to none.

The aperture of the great telescope, which will form the central feature of the establishment, will shortly be decided upon in accordance with the condition that it must surpass that of the largest existing instrument—the 36-inch refractor of the LICK Observatory. It is probable that a size between 40 and 45 inches will be selected. A pair of 40-inch discs of glass, which were made some time ago for the University of Southern California, are now for sale, and these may possibly be obtained.

The mounting of the telescope is already under discussion, and its general features have been decided upon. The quick and

* Abstract of an article in *Astronomy and Astro-Physics* for November, 1892.

slow motions of the telescope, clamping in right ascension and declination, rise and fall of the floor upon which the observer stands, rotation of the dome, etc., will all be operated by electric push-buttons within easy reach of the astronomer at the eye-end of the instrument. They will also be under the control of an assistant seated at a table on the rising floor. Electric devices for operating large telescopes have not hitherto been employed, even on the great LICK telescope. They were long ago suggested, however, by Sir HOWARD GRUBB and Dr. DAVID GILL.

The diameter of the dome will naturally depend upon the focal length of the telescope, but it will probably be in the neighborhood of 85 feet. As in the case of the LICK Observatory and the new Naval Observatory at Washington, the entire floor of the observing room will be made to rise and fall by means of hydraulic rams. The cumbrous observing chair once in vogue is thus done away with, and the utmost convenience to the astronomer secured.

The remainder of the observatory's equipment is still undetermined, but it will probably include a 16-inch refractor, 12-inch "twin" equatorial, with visual and photographic objectives, 6-inch meridian circle, and 20-inch siderostat.

But the equipment of an observatory is only a means to an end. It is intended that the YERKES Observatory shall be devoted to investigation, and even at this early day an outline of the work which may profitably be undertaken will not be without interest.

In the field of general research the YERKES telescope should be applied to the search for new satellites, the study of faint and difficult details of planetary markings, the measurement of BURNHAM'S more difficult doubles, and many similar observations. In stellar spectroscopy a great opportunity will be open, for the immense light-grasping power of the new objective will allow the spectra of stars now beyond our reach to be investigated. The work so ably began by KEELER at the LICK Observatory on the spectra and motions of the planetary nebulæ should be continued and extended. A new departure in the work of large observatories will be the inauguration of a more extensive study of the Sun than has previously been undertaken. This department will be the special province of the writer, and plans for the work have been fully matured.

In applying on a large scale the photographic methods devised

and now in use at the KENWOOD Observatory, and in adding to and extending them, it will for the first time be possible to completely investigate every variety of solar phenomena. The corona should perhaps be excepted, but it is not altogether impossible that a new instrument now being constructed at the KENWOOD Observatory for the purpose of photographing it in full sunlight may prove a success. With an automatic apparatus, also devised here recently, photographs of the Sun, showing all of the phenomena of its surface, will be taken at intervals of about five minutes throughout the day. Photographs will also be taken at frequent intervals with a 12-inch photographic objective and amplifying lens, showing the Sun on a scale of about four inches to the diameter, and others of individual spots on a scale of sixteen inches to the diameter. A spectroheliograph will be so attached to the great telescope that photographs of groups of faculæ and prominences may be taken on a scale of about seven inches to the Sun's diameter, and also by the use of an amplifying lens, on a scale of sixteen inches to the diameter. These photographic observations will be supplemented by simultaneous visual observations, and the spectra of faculæ, spots and prominences will be investigated both photographically and visually. Various special investigations on the Sun will also be undertaken, and the records of self-registering magnetic instruments will assist in the solution of the perplexing question as to the relation existing between solar and terrestrial phenomena.

The astronomers who are to be in charge of the other departments of work having not yet been appointed, no more definite plans can at present be formulated for the investigations other than solar. It is hoped that the importance of the observatory will be measured rather by its work than by its instruments, and that the expectations naturally raised by so perfect an equipment will not be disappointed.

KENWOOD OBSERVATORY, University of Chicago,
October 17, 1892.

THE METEORS OF NOVEMBER 23, 1892.

BY DANIEL KIRKWOOD, of Riverside, California.

The shower of meteors on the evening of November 23, 1892, was, in Southern California, a very brilliant one. The display was not expected till two or three days later, so that we were

taken by surprise at early twilight on the evening of the 23d. The state of the writer's health decidedly forbade long and late watching. A count of thirty minutes in the early part of the evening gave 150 meteors as a result. Some of my neighbors, however, saw greater numbers. Later in the evening an intelligent and trustworthy young gentleman counted 350 meteors in half an hour, or at the rate of 700 per hour. The whole number between 8 and 11 o'clock was probably not less than 1000. The usual radiant was observed. It may be worthy of remark that the same section of the cometary orbit, or nearly the same, was crossing the Earth's path at this time as on the night of November 27, 1872; but the following part, or that which brought up the rear, in November, 1885. A careful study of the structure and phenomena of such parts of the cometary mass as may present themselves from year to year may unexpectedly afford the means of solving some problem of chemical structure.

The phenomena had disappeared on the night of the 24th.

POGSON'S COMET OF 1872.

By W. H. S. Monck.

Some time ago I called the attention of the members of this Society to the probability of a return of Pogson's comet of 1872 during the present year. I have since met with an observation of probably the same comet which indicates a period of about 7 years and a consequent return in 1893.

The observation was made by Mr. Buckingham on November 9, 1865, who then saw "two round vapory bodies near each other; after watching several minutes motion was detected (from n. f. to s. p.) in the smaller one, which appeared most condensed but without any sign of nucleus, but yet with a defined outline." (*Monthly Notices R. A. S.* Vol. xxvi, p. 271.) The positions given by Mr. Buckingham for the two objects are:

	R. A.	N. P. D.
A..	$23^h\ 19^m\ 3^s$.	(Some minutes N. of B.)
B..	$23^h\ 19^m\ 12.75^s$.	$77°\ 25'$.

The comet was, perhaps, also observed by Mr. TALMAGE on November 4, 1869, though he did not notice its duplicity. His position is:

R. A.	N. P. D.
$22^h\ 54^m\ 45.47^s$.	$76°\ 33'\ 39''$.

I may remark that POGSON does not describe the comet seen by him as double. The supposed duplicity rests on the hypothesis (suggested apparently by theoretical reasons) that the bodies which he saw on the 2d and 3d of December, 1872, were distinct. His positions are:

	R. A.	N. P. D.
Dec. 2..	$14^h\ 7^m\ 27^s$.	$124°\ 46'$.
Dec. 3..	$14^h\ 22^m\ 2.9^s$.	$125°\ 4'\ 28''$.

(TENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to W. R. BROOKS, Esq., Director of the Smith Observatory at Geneva, New York, for his discovery of an unexpected comet on August 28, 1892.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHAS. BURCKHALTER.

October 28, 1892.

(ELEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor E. E. BARNARD for his discovery of an unexpected comet, by photography, at Mt. Hamilton, on October 12.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHARLES BURCKHALTER.

OBSERVATION OF THE NOVEMBER METEORS.

By C. D. Perrine.

"Coming home from the train last evening from 6:30 to 6:35 my attention was attracted to the great number of meteors. In that interval I counted thirty-one.

"I observed from 7:32 to 8:50, and in this interval of 1^h 18^m counted 1013 (one thousand and thirteen).

"An observation of a few moments again at 10:15 showed them seemingly as frequent as before.

"With the exception of possibly a half-dozen, all seemed to radiate from *Andromeda*. About a dozen were quite conspicuous, leaving trains of fire visible for from five to ten seconds.

"Weather clear, with high N. wind."

Alameda, Cal., November 24, 1892.

THE OBSERVATORY OF ALGIERS.

NOTICES FROM THE LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

ENLARGEMENTS OF THE LICK OBSERVATORY PHOTOGRAPHS OF THE MOON.

Mr. A. L. COLTON, Assistant Astronomer, is now devoting a large part of his time to enlarging the original negatives of the Moon, previously obtained. One series of enlargements is made on 8 x 10 plates to a scale of Moon's diameter = 3 Paris feet. Quite a number of plates to this scale have already been obtained, and some of them have been carefully studied in connection with MAEDLER'S, LOHRMANN'S and SCHMIDT'S maps. In one respect (only) the latter maps seem to be superior to the enlarged plates: They give extremely small craters which are often not to be clearly distinguished on the photographs. The reason of this is, I think, that the rapid plates on which the original negatives (in the focus) must be taken, have a comparatively coarse grain; so that objects of small angular dimensions are confounded with the grain of the sensitive film. If quick plates with a fine grain can be manufactured, as seems probable, the negatives in the focus will be much improved in this regard, for experiment has shown that the deficiency in this matter is almost solely due to the plates themselves, and is not a deficiency of telescopic definition. In every other respect a transparency on glass enlarged from our negatives must be pronounced to be vastly superior to the maps. The maps give only the baldest outlines of the lunar topography and even these are given in a strictly conventional way, without any true plastic effect, while the transparencies are very satisfactory in all respects, both as maps and as pictures. The wonderfully beautiful drawings of lunar landscapes enlarged from our negatives by Professor WEINEK, reproduced by heliogravure, are also very satisfying and marvelously accurate, as I have had frequent occasion to know through pains-

taking comparisons between them and the negatives. One of these (*Mare Crisium*) will be printed in an early number of our *Publications*. Still, it is not possible for any artist, no matter how diligent, to produce such representations of the whole of the Moon, in all its varying aspects of illumination and libration, for the simple reason that a life is not long enough. Professor WEINEK is obliged to spend from 100 to 200 hours in making a single plate. It is necessary, therefore, to depend upon the Camera for the general representation, leaving specially interesting regions to be specially studied by the artist.

Some portions of the Moon have already been enlarged to a scale of the diameter = 6 Paris feet (the same as that of SCHMIDT'S maps), with great success, and a few craters have been enlarged far more than this. It is hoped to reproduce some of these shortly. The general result of our work of enlargement so far is that each plate brings a multitude of new features to light, and that these are all exhibited in their true relations. If anyone is seeking to make a catalogue of new rills or new craters, such negatives afford a simply boundless field. But, better than this, they give a perfectly true picture of the lunar surface, in which there is no need for conventional signs for slopes or hollows. It requires but a moment to compare such a picture taken last year with the Moon itself, and to decide whether or no a change has occurred. I need not say that such a decision based on the comparison of *maps* and Moon is very difficult and unsatisfying. If lunar geology is ever to be studied in detail, it must have such pictures as a basis. The chief problem yet to be solved is how to reproduce our negatives in large editions, so that they may be as available to others as they are to us. The heliogravure process is almost entirely satisfactory in this respect, but it is, unfortunately, very expensive. Another most serious practical difficulty is, the coarse grain of the sensitive films employed in making the original plates.

The results already reached, in spite of these drawbacks, entirely confirm my previously expressed opinion that the future of lunar studies must rest, in the main, upon photographs, and that the photographs already available to science are of more value than all preceding data obtained by other methods.

It is hoped to print in these *Publications*, during 1893, some reproductions of our enlargements, which will justify this judgment.

E. S. H.

To What Stellar System Does Our Sun Belong? [by Professor J. C. Kapteyn].

From *Koninklijke Akademie van Wetenschappen te Amsterdam, Afdeeling Natuurkunde, Zitting van 29 April, 1892.*

[Translation and Abstract from the original Dutch by E. S. H.]

"Professor Kapteyn discussed the question of the distribution of stars in space. Up to this time investigations upon this distribution have set out from the assumption that in the present state of science the distances of the fixed stars could best be estimated by a consideration of their proper motions. Investigations by Safford, Plummer, Stumpe, etc., have approached the question from that side. Professor Kapteyn has made a comparison between the *spectral-type* of the stars and their different proper-motions. The spectral-type for each star is taken from the Draper Catalogue of Pickering; the proper-motion from Stumpe's list in *Astronomische Nachrichten*, Nos. 2999–3000. Of the 1054 stars in this list, 476 stars brighter than the 7.0 magnitude were found in the Draper Catalogue. The others were either too faint or too far south. Besides these stars 115 others with small proper-motions (in R. A., less than $0^s.003$, in Decl., less than $0''.03$) were included from Auwers' Bradley. If we call Q the quotient obtained by dividing the number of stars of Type II* by the number of stars of Type I*, and if we arrange the data in the order of the proper-motions we obtain the following table:

Proper-Motions.	Mean Proper-Motion.	No. of Stars. Type I.	No. of Stars. Type II.	No. of Stars. Type III.	Q
From 7″.0 to 0″.7 ...	1″.39	3	51	—	17.0
" 0 .7 " 0 .4 ...	0 .92	12	66	1	5.5
" 0 .4 " 0 .3 ...	0 .35	14	66	—	4.7
" 0 .3 " 0 .2 ...	0 .24	34	124	—	3.65
" 0 .2 " 0 .16...	0 .18	35	67	3	1.9
Small.............	Small.	79	35	1	0.44

* Type I consists of stars whose spectra are like that of *Sirius*.
Type II " " " " " our Sun.

"From this table the following conclusions can be drawn:

"The nearest neighbors of our Solar-system are almost exclusively stars of Type II (like our own sun); as we go further from the sun the number of stars of the first type relatively to the number of those of the second regularly increases, proportionately to the distance (or at least inversely proportional to the proper-motion) until we reach a distance which corresponds to a proper-motion of approximately $0''.2$.

"With removal to still greater distances the stars of the first type predominate, so that if we include those BRADLEY stars whose proper-motion is so small as to be hardly determinable with accuracy, we shall find about twice as many of the first type as of the second among them.

"The DRAPER Catalogue contains few stars south of Declination $-25°$. Certain considerations make it very probable, however, that the stars of the southern hemisphere are similarly distributed.

*   *   *   *   *   *   *

"Professor KAPTEYN next examined the two following questions:

"1°. Is our Solar-system situated exactly in the centre of the (stellar) system—that is, in that place where the stars of Type II are most numerous?

"2°. What relation does the Milky Way bear to the System?

"Various considerations lead to the general conclusion that the form of our stellar-system may be like that of a sphere surrounded by a ring. Investigations now in progress will throw much light on these questions."

PHOTOGRAPHS OF THE PHENOMENA WHICH ACCOMPANY THE INGRESS OF THE SHADOWS OF THE SATELLITES OF *JUPITER*.

The photographs of *Jupiter* (enlarged direct with the new BRASHEAR amplifier, which magnifies 5 diameters), on October 24th of this year are especially interesting. They cover the time from $7^h\ 27^m$ to $14^h\ 18^m$ (when the sky became hazy), and show the shadows of Satellites I and II on the disc, the *egress* of I from transit, the *ingress* of the shadow of II, etc. The latter phenomenon took place at about $7^h\ 35^m$ P. S. T., by the American Ephemeris. The corresponding negative has nine images on it which were made at the following times:

1..7^h 37^m 4^s— 8^s P. S. T.	2..7^h 37^m 38^s—41^s P. S. T.
3.. 38^m 8^s—10^s "	4.. 38^m 44^s—48^s "
5.. 39^m 15^s—18^s "	6.. 39^m 48^s—50^s "
7.. 40^m 24^s—28^s "	8..7^h 40^m 51^s—54^s "
9..7^h 41^m 21^s—23^s "	

The definition in these images is very sharp. The shadow of II is elongated on all of them, and its longest dimension points nearly in the direction of the shadow of I (which is on the disc). In the first three impressions (1, 2, 3, above), the shadow is markedly longer than it is wide; in the next three, it is about one-and-one-half times as long as wide; in the last three it is nearly twice as long as wide. We have thus succeeded in photographing a phenomenon which was first seen visually here in 1888 (by Messrs. SCHAEBERLE and KEELER, and subsequently by others). The full description of the visual observation is given in these *Publications*, Volume III (1891), page 264, *et seq.* The phenomenon is not easy to explain. That it was a real one was fully shown by the visual observations, and now the photographs can be adduced in confirmation of it. The shadow of I was well on the disc and is round in the photographs, just as shadows in this situation appear to the eye. E. S. H.

PAPERS ON THE PERSONAL EQUATION [BY EDMUND C. SANFORD, PH. D., OF CLARK UNIVERSITY].

Dr. SANFORD has printed in the *American Journal of Psychology*, for November, 1888, and February and May, 1889, three valuable papers on the personal equation: No. I gives a brief historical account of the discovery and of the chief general studies on personal equation, going into considerable detail, and describing the various ways which have been proposed for determining its amount, and the devices for excluding it from observation. No. II treats of variations in its amount for different objects and under varying conditions, and No. III discusses the nature and the cause of personal equation from the standpoint of the psychophysicist. An appendix gives an extensive (though not exhaustive) and valuable bibliography of works dealing with the subject in both its astronomical and its physiological relations.

E. S. H.

THE FIFTH SATELLITE OF *JUPITER*.

Just as the last pages of Number 25 of the *Publications* were going to press we had the pleasure of inserting Professor BARNARD'S original telegram announcing the discovery of a fifth satellite to *Jupiter*. Regarding his search for new objects, and the resulting discovery of the satellite, we shall quote his own account as published in the *Astronomical Journal*:

"Nothing of special importance was encountered until the night of September 9, when, in carefully examining the immediate region of the planet *Jupiter*, I detected an exceedingly small star close to the planet, and near the third satellite. I at once measured the distance and position angle with reference to Satellite III. I then tried to get measures referred to *Jupiter*, but found that one of the wires had got broken out and the other loosened. Before anything further could be done the object disappeared in the glare about *Jupiter*. Though I was positive the object was a new satellite, I had only the one set of measures, which was hardly proof enough for announcement.

"I replaced the wires the next morning. The next night with the great telescope being Professor SCHAEBERLE'S, he very kindly gave the instrument up to me, and I had the pleasure of verifying the discovery, and secured a good set of measures at elongation.

"Just what the magnitude of the satellite is it is at present quite impossible to tell. Taking into consideration its position, however, in the glare of *Jupiter*, it would, perhaps, not be fainter than the thirteenth magnitude."

The recent observations of the satellite give about $11^h\ 57^m\ 20^s.5$ for its period of revolution, and about 112,510 miles for its mean distance from the planet's centre. The plane of its orbit appears to be the common plane of all the satellites, but its orbit is probably more eccentric than those of the other satellites. Its diameter is probably in the neighborhood of 100 miles.

The satellite has been seen and a few observations secured with the 26-inch telescope of the University of Virginia, with the 23-inch telescope of Princeton College, and with the 18-inch at Evanston. Unfortunately, the great equatorial of the Naval Observatory in Washington is dismounted and undergoing removal to the new observatory buildings.

Thus far the satellite does not appear to have been observed

with any of the great European telescopes. This is probably on account of the unfortunate fact that the LICK Observatory telegrams were seriously changed during transmission, and the observers were led to expect the satellite at elongation at wrong times. However, it is probable that sufficient observations will have been obtained during the opposition upon which to base a thorough investigation of the orbit. E. S. H.

DR. GILBERT ON THE EVOLUTION OF THE MOON.

[At a meeting of the National Academy of Sciences, held at Baltimore, November, 1892, Dr. G. K. GILBERT, of the U. S. Geological Survey, presented a memoir on the Evolution of the Moon. An abstract of this paper is given in the *American Naturalist* for December,' and is reprinted below. In this connection the reader should refer to these *Publications*, Volume IV, p. 37, where an observation of Dr. GILBERT'S on a crater in Arizona is described. This crater was actually formed by a falling meteor. So far as I know, Dr. GILBERT is the first geologist of high standing to give his authority to the hypothesis that lunar craters have, *in general*, been formed by the bombardment of the lunar surface by meteorites. My own studies on Moon photographs do not lead me to the same conclusion. I hope that some of the selenographers of the Society, Messrs. WEINEK, ELGER, RANYARD and others, may be willing to treat this question in the *Publications*.—E. S. H.].

"Dr. GILBERT said in part: 'The surface of the Moon, like that of the Earth, is diversified by plains, uplands and mountains, and these various features have special characters in which they differ from those of the Earth. The plains lie lower than other portions of the surface, and are distinguished by their darker color. By those who have mapped the surface of the Moon they are called seas, but the word is used in a figurative sense, for it is well understood that there is no water on the Moon. The mountains are usually in the form of rings, each ring inclosing a hollow, and to this form the name crater is given. They are scattered over the surface of the plains, and on the uplands they are thickly set, overlapping one another in every variety of relation. They are of all sizes, from the smallest that the telescope can discern to a diameter of several hundred miles. Those of medium and larger size are usually characterized by a smooth circular plain in the interior and a hill or group of hills rising in the center of the plain. They differ from the craters of the Earth in various ways, especially in the fact that their bottoms are below the level of the surrounding country, and in the fact that the central hill bears no crater on its summit.

" 'The origin of these craters has been the subject of many theories. Despite their marked peculiarities of form, they have more commonly been ascribed to volcanic action; but they have also been referred to the bursting of gigantic bubbles, to the evaporation of water and its accumulation about the point of evaporation, as ice, and to the impact of bodies from without. Personally, I favor the last mentioned explanation, but I differ from other writers in respect to the origin of the colliding bodies. It has been previously surmised that these might be rocks hurled from terrestrial volcanoes; that they might be meteors from the recesses of space, such as are continually burned in the upper layers of our atmosphere, giving rise to shooting stars, and that they might be aggregates of such meteors constituting balls of cosmic dust. Now, my idea of their origin is based upon the phenomena of the planet *Saturn* and its ring. About that planet is a disc-like ring which astronomers believe to be constituted of an indefinitely large number of very small bodies revolving about the planet in parallel orbits—a symmetrically shaped form of small satellites. Assume that a similar ring of minute satellites once encircled the Earth, and that those gradually became aggregated into a smaller number of larger satellites, and eventually into a single satellite—the Moon. The craters mark the spots where the last of the small bodies collided with the surface when they finally lost their independence and joined the larger body.' "

Discovery of Asteroids by Photography.

The remarkably rapid advance made in many lines of astronomical research since the introduction of dry-plate photography is nowhere more marked than in the discovery of the asteroids. *Ceres*, the first of the small planets, was discovered the first day of this century, and a few years later three others were found. A fifth was not added until 1847; but since then they have been searched for systematically, with wonderful patience, by Peters, Watson, Palisa, and many other noted astronomers. One year ago the number had reached 322. No. 323 was discovered photographically by Dr. Wolf, of Heidelberg, and in the past year he has detected twelve other new planets on his plates. A single negative recorded four planets, two new ones and two previously discovered. Charlois, of Nice, discovered two by visual methods early this year; but later he adopted the photo-

graphic method, and has recently added three discoveries. In the past year PALISA has discovered two by the older methods. 342 are now known, and at the present rate of discovery the resources of the computing staff in Berlin will soon be severely taxed to furnish satisfactory orbits for them.

CHARLOIS has assigned to the first asteroid discovered by him in 1892 the name *Columbia*, in honor of our quadri-centennial year.

WOLF has named the first planet discovered by him *Brucia*, in honor of Miss BRUCE, who has made generous contributions of money for astronomical research.

W. W. C.

ELEMENTS OF COMET *e*, 1892 (BARNARD, Oct. 12).

From Mr. BARNARD'S observations of October 13, 19 and 25, I have computed new parabolic elements of the comet discovered by him with the CROCKER photographic telescope. They are:

$$T = \text{Gr. M. T., 1892, Dec. } 2^{d}.5977$$

$$\left.\begin{array}{l} \omega = 165^{\circ}\ 44'.51 \\ \Omega = 201\ \ 49\ .34 \\ i = \ \ 33\ \ 35\ .93 \end{array}\right\} 1892.0$$

$$\log q = 0.18528$$

Residuals (Obs.—Comp.).

$$\cos\beta'.\,\Delta\lambda' = +0'.64$$

$$\Delta\beta' = \ \ 0.00$$

The residual in longitude is large, but another approximation to a parabolic orbit does not reduce it. This fact, taken in connection with the direct motion and the fairly small inclination, points strongly to an elliptic orbit. However, the first observation depends only upon a *Lalande* star place, and the character of the orbit cannot now be decided.

The original elements, distributed by telegraph, represented the observations upon which they were based very well; though, as stated in the telegrams, they were subject to considerable uncertainty.

W. W. C.

October 27.

NOTE.—Elliptic elements by Professor KRUEGER, of Kiel, Germany, just received, assign to this comet a period of 10 years. Elements by SCHUELHOF assign a period of about 6 years, and indicate a close relation to WOLF'S periodic comet.

ANCIENT COMETS.

In a work of extraordinary erudition which has been presented to the Library of the LICK Observatory by Professor PICKERING of the Harvard College Observatory* I find (in the Index) twenty-four references to *comets* which have appeared. Nearly all of these references should be consulted by anyone who is compiling a catalogue of historic comets. Three of them contain something noteworthy.

I therefore copy these three extracts:

Page 471: "14 A. D. = 1st year of the 'thiang-foung' of the usurping Sinmang" or Wang-mang—(Chinese Chron. table). "The same year" and "before the death of AUGUSTUS" (Clint. iv. page 45) a *comet*. Observed by L. SENECA, nat. qu. i, 1. [This is No. 54 of WILLIAMS' Chinese Comets, page 54.]

Page 475: "19 A. D." (Tacit. and Clint.) Visit to Egypt of GERMANICUS; and his death on his way thence in Syria. At this time a *comet* observed by L. SENECA, nat. qu. i, 1 (Clint. iv. p, 45).

Page 477: "31 A. D." (Sueton., Dio. and Clint.) disgrace and death of SEJANUS, prefect of the prætorian guard and consul for this year. A *comet* visible at the time, witnessed by L. SENECA, nat. qu. i, 1 (Clint. iv. p. 45). E. S. H.

SCIENTIFIC VISITORS TO THE LICK OBSERVATORY.

Professor W. D. ALEXANDER of Honolulu, Chief of the Geodetic Survey of Hawaii, made a visit to the LICK Observatory during the month of September. Mr. E. D. PRESTON of the U. S. Coast and Geodetic Survey made a determination of the force of gravity at Mount Hamilton, September 27–October 1, using the new short-pendulum apparatus, devised by Professor MENDENHALL. This is the third determination of gravity at L. O., the first having been made by Mr. PRESTON, with one of the PEIRCE seconds pendulums, in 1883 (*Publ. A. S. P.*, Vol. I, page 125), and the second by Professor MENDENHALL, in the summer of 1891 (*Publ. A. S. P.*, Vol. III, page 282). E. S. H.

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* Chronological History of Plants: Man's Record of His Own Existence, illustrated through their names, uses and companionships; by CHARLES PICKERING, M. D. Boston, 1879: quarto.

THE TOTAL SOLAR ECLIPSE OF APRIL, 1893.

A letter lately received from Dr. JOHN THOME, Director of the National Observatory of the Argentine Republic, Córdoba, announces that he intends to observe the total eclipse of April, 1893, "on or near the railway and telegraph line to Salta" from Rosario de la Frontera, Argentine Republic. The object of the expedition will be to observe the contacts, to search for *Vulcan* and to secure photographs of the Corona. E. S. H.

DISCOVERY OF COMET *e*, 1892.

Professor BARNARD found Comet *e* 1892 recorded on one of his photographs of the Milky-Way on October 12. It was observed visually on October 13 and its orbit has been computed by Professor CAMPBELL. See these *Publications*, page 265.

E. S. H.

JUPITER AND HIS SYSTEM* [BY MISS ELLEN M. CLERKE].

While Miss AGNES CLERKE is making an excursion into antiquity in her recent book (Studies in Homer), and has temporarily deserted Astronomy after printing her two admirable volumes (The History of Astronomy in the XIX Century, and The System of the Stars), her sister, Miss ELLEN CLERKE, comes forward with a capital little pamphlet on *Jupiter* and His System. In about forty small pages a complete popular account of our present information regarding this planet and its satellites is given, in an interesting and straightforward way, equally removed from dullness and from the faintest trace of "smart writing." Members of the Society will do well to read this little book. E. S. H.

WHO OWNS AN AEROLITE?

"DES MOINES (Iowa), October 4, 1892.

"On May 2, 1890, an aerolite weighing sixty-six pounds fell on the land of JOHN GODDARD, in Winnebago County. PETER HOAGLAND dug it up and conveyed it to his house, and sold it as

* Published by STANFORD, 27, Cockspur St., London. Price, 1 shilling.

his own to H. V. WINCHELL for $105. GODDARD claimed that the meteor was his, as it fell on his land. HOAGLAND claimed it, as he discovered it first and as it fell from heaven.

"The matter resulted in a suit, which was decided to-day. The Court held that the stone became part of the soil on which it fell, and that HOAGLAND had no right to remove it. The defense claimed that whatever was movable and found on the surface of the earth, unclaimed by any owner, was supposed to be abandoned by the proprietor. The Supreme Court has just ruled that as this stone was in the earth and practically unmoved, and was placed there by nature, it was a stone included generally under the property to be claimed. The case is unique, with no established precedent."—*Telegram to the S. F. Chronicle.*

THE OBSERVATORY AT ALGIERS.*

The cut facing p. 257 is copied from Lieut. WINTERHALTER'S Report on European Observatories by the kind permission of the Superintendent of the U. S. Naval Observatory (*See Publ.* A. S. P. Vol. III, page 40). The note here given is condensed from the text of Lieut. WINTERHALTER'S Report.

The Observatory of Algiers (founded in 1886) is the direct successor of the provincial observatories which were founded in the early days of French possession.

Its chief instruments are an *Equatorial Coudé*, a meridian-circle, two large reflecting telescopes, and a photographic refractor which will be used in making a section of the International photographic charts of the sky, spectroscopic apparatus, etc. The Sun is regularly photographed here, and it is an interesting proof of the clearness of the sky that photographs of the Sun were secured in 1883 on no less than 310 days.

The latitude of Algiers is $+36° 45'$; so that is a little to the south of Mt. Hamilton ($+37° 20'$). E. S. H.

LIBRARY OF THE COLUMBIA COLLEGE OBSERVATORY, NEW YORK.

The following interesting circular has lately been received :

"The library of the Columbia College Observatory has been enriched lately by the purchase of the private library of Mr. STRUVE, former director of the Pulkowa Observatory. This

* C. TREPIED, Director.

library contains 4361 books and 3056 pamphlets. This important addition gives us now a fine equipment of over 10,000 volumes.

"The Observatory desires to keep this collection up to date, and respectfully requests that it may be favored with your publications. Very respectfully,

"J. K. REES,

"Director of the Observatory."

TRANSLATION OF SCHEINER'S SPECTRALANALYSE.

All who are interested in the spectroscope as applied to the solution of astronomical problems will be pleased to learn that *Die Spectralanalyse der Gestirne*, by Dr. SCHEINER, Astronomer in the Royal Astro-Physical Observatory at Potsdam, is to be translated into English. It will also be revised and enlarged to include the results of the last three years, thereby bringing it up to date. The work is being done, with the assistance of the author, by E. B. FROST, of Dartmouth College Observatory, and is expected to be completed within a year. W. W. C.

DUPLICATES IN THE LIBRARY OF THE LICK OBSERVATORY.

The following works are duplicate in the Library of the L. O. and we should be glad to exchange them for any works which are lacking in our collection—especially for a set of the maps of the northern DM. E. S. H.

American Journal of Science: Nos. 145–156 inclusive; 1883 complete, 8vo, paper.

ARGELANDER: Abo observations 1, 2, 3 complete; bound in 1 vol., folio, half morocco.

BALL: Elements of Astronomy. 1 vol., 16mo, cloth.

BERLIN: Astronomisches Jahrbuch. 8vo. 1882 (cloth), 1883 (cloth), 1883 (paper), 1884 (cloth), 1885 (cloth), 1886 (cloth), 1886 (paper), 1887 (cloth), 1887 (half morocco), 1887 (paper), 1888 (paper). 11 vols.

BODE: Astronomisches Jahrbuch, 1795, 1796, 1797, 1798, 1800. 5 vols (cloth).

HERSCHEL and MAIN: Catalogue of Double Stars, 1874. 4to, half roan.

LAMONT: Munich Star Catalogues, 6 vols. Complete, 8vo, half roan.

LONDON: *Memoirs R. A. S.*, vol. 24, 1856. 4to, half roan.

MADRAS: Observations, 1862–3–4. 1 vol., 4to, cloth.

MAEDLER: Dorpat Observations, vol. 13, 1856. 4to, half roan.

PARIS: Annuaire Bureau des Longitudes, 1876 and 1877. 2 vols., 16mo, paper.

WASHINGTON: U. S. Naval Observatory. Eclipse Report of 1878. 4to, cloth.

WASHINGTON: U. S. Transit of Venus Commission Report 1874. I, 4to, cloth.

PRELIMINARY NOTE ON TERRESTRIAL ATMOSPHERIC ABSORPTION OF THE PHOTOGRAPHIC RAYS OF LIGHT.

As the tabular data below may be of immediate use to some astronomers, I have thought it well to publish them at once. They are deduced from an extended investigation which I took up in 1889 at the suggestion of Professor HOLDEN. The observations (exposures), measures, and the method of reduction, form the subject-matter of a memoir now being published by the University of California.

The final results are based upon four different series of observations, as follows:

First Series, at Mt. Hamilton, in September, 1889.
Second Series, at Cayenne, S. A., in December, 1889.
Third Series, at Mt. Hamilton, in July and August, 1890.
Fourth Series, at Mt. Hamilton, in November, 1891.

The exposures for the third series were kindly made for me by Professor CAMPBELL, who at the time was spending his vacation at the LICK Observatory; the other three series of exposures were made by myself. All the observations, with the exception of those belonging to the fourth series (which were made with our CROCKER telescope) were made with a 6-inch equatorially mounted DALLMEYER lens belonging to the United States Naval Observatory, and loaned to the LICK Observatory primarily for the purpose of taking it to our eclipse station at Cayenne.

Before the reduction of the observations on atmospheric absorption of the photographic rays of light could be undertaken it was evidently necessary to determine the relation which exists, for the given telescope, between the diameters of the stellar images for known exposure times and the brightness of the corresponding stars. Some results of an investigation on this subject

will be found in the *Publications of the Astronomical Society of the Pacific*, Vol. I, No. 4. See also *Astronomical Journal*, No. 269.

It is not necessary for me to make any extended remarks as to how the observations were made and reduced, as the memoir on this subject will soon be in the hands of astronomers.

The final empirical expression which represents the law of photographic absorption is one of a series (for each of which nearly the whole mass of material was worked over by the method of least squares) which best represents all the observations. I found that

If B_0 denotes the photo-brightness of a star in the zenith,
B " " " " at the zenith distance ζ degrees, and f a constant for a given state of the atmosphere, then

$$B = B_0 \left[1 - f.\ \tan\left(\left(\frac{\zeta}{12}\right)^2\right)\right]^2$$

In this expression $(\frac{\zeta}{12})$ is to be regarded as an abstract number, whose square expresses the number of degrees of which trigonometrical tangent is required. For a normal condition of the atmosphere and for *Sirian* type stars, the value of the factor f is 0.60.

The tables given below are computed for these conditions, using the same light ratio for the photographic magnitudes that is employed in visual determinations.

The argument for entering the table is the observed zenith distance, the corresponding function is the amount of the (photographic) atmospheric absorption expressed in photographic *magnitudes*.

Observed Z. D.	Photographic Absorption	Observed Z. D.	Photographic Absorption	Observed Z. D.	Photographic Absorption	Observed Z. D.	Photographic Absorption
	mag.		mag.		mag.		mag.
0°	0.00	50°	0.44	71°	1.2	81°	2.1
5	0.00	55	0.56	72	1.2	82	2.2
10	0.01	60	0.71	73	1.3	83	2.3
15	0.04	65	0.89	74	1.4	84	2.5
20	0.07	70	1.12	75	1.4	85	2.7
25	0.11	75	1.45	76	1.5	86	2.9
30	0.16	80	1.94	77	1.6	87	3.3
35	0.21	85	2.68	78	1.7	88	3.7
40	0.28	90	5.00	79	1.8	89	4.2
45	0.35			80	1.9	90	5.0

These values are to be added to the (unknown) absorption in the zenith to obtain the absolute absorption.

In presenting the above results to astronomers for practical use, I feel quite confident that they will be sufficiently accurate for all exposures made on SEED plates sensitometer No. 26, which have been *fully* developed. J. M. SCHAEBERLE.

MOUNT HAMILTON, October 20, 1892.

In celestial photography it is very desirable to have some simple and convenient method of doing away with the reflection from the back of the photographic plate. Especially is this the case when it is desired to obtain representations of very faint objects in the immediate neighborhood of very bright stars. Some experiments which I have made led up to the following simple and effectual method:

On the photographic plate, held in a horizontal position, film side down, a number of drops of clean water are allowed to fall near the centre of the plate; a piece of red glass* is then placed upon this water in such a way that no air spaces can be formed between the two glass surfaces. The capillary attraction will keep the water between the glass surfaces, and a border frame of blotting paper will keep any stray water from reaching the film side of the plate. Folding "book" plate-holders (like the "Daisy") may be used to keep the glasses pressed together during the exposure. The difference between the density of glass and water being much less that of air and water, nearly all the blue rays which have passed through the film now easily enter the red glass surface and are absorbed.

After the exposure of the plates, the whole combination can be placed in the developing tray before the removal of the red glass, if so desired. J. M. SCHAEBERLE.

ERRATA IN *PUBLICATIONS* NO. 25.

By an error of the printers the advertisements at the end of No. 25 of the Publications were printed on page 204 (the reverse of page 203). Members are requested to remove page 203 (end of No. 25) when binding the present volume. The pagination will then be correct. THE COMMITTEE ON PUBLICATION.

On page 199 the numbering of the Satellites of *Jupiter* in the order of occultation should read IV, II, I and III. J. M. S.

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* Somewhat smaller than the sensitive plate.

Minutes of the Meeting of the Board of Directors held in the Society's Rooms November 26, 1892.

President SCHAEBERLE presided. A quorum was present. The minutes of the last meeting were approved.

The following members were duly elected. An asterisk (*) is added to the names of life-members.

List of Members Elected November 26, 1892.

Prof. W. D. ALEXANDER	Honolulu, Hawaiian Islands.
WM. HOWAT	358 William Street, Melbourne, Victoria.
Prof. ALEX. S. HUNTER	Hanover, Indiana.
W. H. IZZARD	20 Boston Park Road, Brentford, W. England.
Prof. JEFFERSON E. KERSCHNER	Daniel Scholl Observatory, Lancaster, Penn.
Miss HANNAH TOWNSEND LAWRENCE	Bayside, Long Island, New York.
THE CITY LIBRARY	Lowell, Mass.
JOHN PATTEN	Harford Avenue and Forrest Street, Baltimore, Md.
Dr. JOHN M. THOME *	National Observatory, Cordoba, Argentine Republic.
Señor FRANCISCO VALIENTE	San José, Costa Rica.

A number of candidates were proposed for the January meeting. The resignations of several members were received and accepted. The Treasurer presented his bi-monthly report, which was received and filed.

The following resolutions were adopted:

Resolved, That the Committee on the Comet-Medal be authorized to present a copy of the medal to the collection of the Royal Society of London, in the name of the Astronomical Society of the Pacific.

Resolved, That the meeting of January 28, 1893, be held at the CHABOT Observatory in Oakland.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, held in the Lecture Hall of the California Academy of Sciences November 26, 1892.

President SCHAEBERLE presided. The minutes of the last meeting were approved. The thanks of the Society were returned to the California Academy of Sciences for the use of their lecture hall. The list of new members elected at the Directors' meeting was read to the meeting.

The following papers were presented:

1. Glacial Epochs, by Dr. JOSEPH LECONTE, of Berkeley.
2. Observations of the Occultations of *Mars* and *Jupiter*, 1892, September 3 and 9, by Professor J. M. TAYLOR, of Seattle.
3. Predictions for the Solar Eclipse of October 20, 1892, by O. E. HARMON, of Chehalis, Wash.
4. Note on Terrestrial Atmospheric Absorption of the Photographic Rays of Light, by Professor SCHAEBERLE, of Mt. Hamilton.
5. On POGSON's Comet of 1872, and
6. On the Radiant Points of Meteor-Streams, both by W. H. S. MONCK, of Dublin.

Six heliogravures made from enlarged drawings of lunar craters by Professor WEINEK from LICK Observatory negatives, and an enlarged glass positive of Cleft of *Hyginus*, made by Mr. A. L. COLTON from LICK Observatory negatives, were exhibited to the meeting.

The chairman then introduced Professor LECONTE, who delivered a most interesting and instructive lecture on the Glacial Epoch. A fuller account of this paper will be given in a subsequent number of the *Publications*.

The Society then adjourned, to meet at the CHABOT Observatory on January 28, 1893, at which time it is expected that an exhibition of astronomical lantern-slides will be given by Mr. BURCKHALTER.

ERRATA IN *PUBLICATIONS* NO. 26.

Page 230, line +20, *for* 1892 *read* 1891.

Page 229, line −24, add: "See also *Astronomical Journal*, No. 279."

OFFICERS OF THE SOCIETY.

OFFICERS OF THE CHICAGO SECTION.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend any or all of the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.